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CONTROL AND PROTECTION OF ELECTRIC SYSTEMS.*

BY
CHARLES PROTEUS STEINMETZ, M.A., Ph.D.,
Chief Consulting Engineer, General Electric Company.
Member of the Institute

WHEN the first commercial electric circuit issued from a station the problem of control and of protection arose. It was a simple problem at first: an ammeter and voltmeter to measure current and voltage; a knife-blade switch to send the current into the desired path, or withdraw it; the fuse to open the circuit in emergencies, and if the wires became crossed and fuse and switch failed, generator and engines stopped, and not much harm was done.

With the extension of the circuits into the suburbs some lightning troubles were felt and led to the introduction of lightning arresters—in the early days based mainly on hope and trust in Providence rather, as very little was known of lightning phenomena.

Since these days, less than a generation ago, enormous changes have taken place, and the electric systems have increased in size, in voltage, and in extension.

Where 100-horse-power machines were large once, now steam turbine alternators of 40,000 horse-power and more are in com-

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mercial operation. The steam engine has made room for the steam turbine, and the steam turbine does not stop when the wires are crossed and a short circuit occurs, and the momentum of the turbine disks, revolving at velocities of 300 to 400 miles per hour, can supply ample energy for the destruction of any part of the system.

Feeders of 10,000 horse-power or more, generators of 40,000 horse-power have to be controlled by switching: an attempt to open such a circuit by the knife-blade switch of old would lead to the destruction of the switch—and probably its operator.

Instead of small machines operating separately on independent circuits, huge generators now feed in parallel into the system of busbars, on which is concentrated all the power of the station or the group of stations which are tied together. Numerous stations and systems of interconnected stations of 100,000 to a quarter million horse-power and over are in operation, and the half-million horse-power mark has been reached.

Anywhere on the busbars of the station or in the feeders near the station there is available, destructively in case of an accident, as a short circuit, not only the entire power of the station, of perhaps half a million horse-power, but the far greater power which the station generators can give momentarily.

Short-circuit currents of forty to fifty times normal full-load current may momentarily flow from some turbo-alternators, representing ten and more times full-load power.

Such a station, or group of closely interconnected stations, of half a million horse-power full-load capacity, may momentarily send into a short circuit at the busbars over five million horse-power. This is the power of Niagara: for Niagara is estimated variously at from 5,000,000 to 15,000,000 horse-power.

It is obvious that no switch or circuit breaker can be built to safely open such power, to suddenly stop Niagara, especially when considering that many hundreds of feeders issue from the busbars, that in any one of these feeders a short circuit in the cable may let loose the power of the entire system, and every feeder thus requires such a circuit breaker.

With half a million horse-power station capacity, a momentary overload capacity ten times as high, assuming that we could build a circuit breaker to open this short-circuit power as quickly as in three to four cycles, or one-eighth second: this would require to

dissipate in the circuit breaker the energy of over 200,000,000 foot-pounds—the destructive energy of 1000 tons dropping from a height of 100 feet. This is about the energy of a projectile of 2000 pounds weight leaving the cannon at the velocity of 2500 feet per second. It is the destructive energy of two heavy railway trains, of 400 tons each, going at sixty miles per hour, and meeting in head-on collision. It is the energy of the explosion of thirty pounds of dynamite.

Equally great has been the increase of voltage: where once 2000 volts were high-voltage distribution, in circuits of a few miles length, now circuits of hundreds of miles length are in operation at voltages of 100,000 to 150,000. Such voltages jump toward any object for over a foot distance, and will maintain arcs of practically unlimited distance; that is, with 100,000 volts and practically unlimited power back of it, an arc can extend for hundreds of feet. Thus no simple switch will open such voltages under power.

Transmission systems at high voltages have been interconnected with each other into networks, which spread and extend, and already to-day often represent thousands of miles of interconnected high-voltage lines, covering tens of thousands of square miles, and picking up every lightning, every atmospheric disturbance within this entire area.

Thus the lightning protection also has become a far larger problem than in the small circuits of old.

But far greater than the energy of any lightning stroke is the energy stored as magnetic field surrounding the conductors, as dielectric field radiating from the conductors of these big transmission systems, and if this internal energy of the system is set surging, its effects are far more destructive than those of lightning, and the effects may not be merely momentary, as those of lightning, but continual, as machine energy continually replaces the stored internal energy, which causes the destructive surge.

And, in addition hereto, far greater reliability and continuity of service is to-day demanded from the electric systems than was in the early days, and that at a lower cost of electric energy, and it must be remembered that, with the increasing cost of living, electricity is one of the few commodities which has steadily decreased in price.

The foremost problem of control of electric systems thus is

that of controlling enormous powers; the foremost problem of protection is that against self-destruction by its own power.

Current and voltage have grown beyond the values for which instruments can be built, and *current transformers* and *voltmeter transformers* are interposed between the circuit and the instruments measuring it. With the general introduction of parallel operation, *power factor indicators* are required to insure the division of load without excessive waste currents; *frequency indicators* and *synchronizing devices* to safely connect machines into the system.

With hundreds of feeders radiating from the generating station, the office of the load dispatcher has become essential, and the necessity of keeping exact records of all operations and of all accidents and incidents is of the greatest importance. Automatic recording devices thus have been developed, as the *multirecorder,* to record, within fractional seconds, all important events, as opening and closing of switches, starting and stopping of generators, surges, lightning disturbances, etc. Such automatic devices afford a valuable check on the operating staff, but more important still is their record in emergencies, where a number of things happen almost at once, where the attention of the operators is detracted from accurate observation by the necessity of action, and the record thus could be made only afterwards from memory, which is not very accurate in such a period of excitement. It is just in such abnormal conditions where the most complete and accurate record is of greatest importance, to enable the engineers to determine with certainty what happened and why it happened, so as to take steps to guard against its recurrence.

Oil circuit breakers have been developed, which can safely and without disturbance close and open the feeder circuits of over 10,000 horse-power, the generator circuits of 40,000 horse-power and more, with an ample margin of overload capacity. In these the circuit is opened under oil with such mechanical arrangement of contacts and oil vessel that in the moment of circuit opening the current is extinguished at the end of a half wave by the rapid expansion and chilling of the oil vapor which is produced by the opening arc, and which in the first moment is under high compression, due to the momentum of the oil, which has to be set in motion.

The most serious danger, in the growth of electric systems, was, however, the possibility of self-destruction by the power let loose under short circuit, and there were anxious years for the operators and managers of these large electric systems before the industry devised the means of safely controlling unlimited power. More than once, when a serious short circuit occurred and a disaster was averted only by luck, the system was cut into two or three sections and these operated independently, to limit the power. But when months passed without further accidents, invariably, due to the requirements of economy and reliability of operation, the sections came together again and parallel operation of the entire system was restored.

This, the most serious problem of the high-power electric system, was solved by the development of the *power limiting reactances.*

In the generator leads, between generators and busbars, are inserted reactances, capable of standing enormous overloads, of a size sufficiently small not to interfere with the normal flow of power, at full load or any overload which the generator may be called upon, but large enough to materially limit the generator current and power at short circuit. Usually the *generator reactances* limit the momentary short-circuit current to about ten to twelve times full-load current; that is, the momentary short-circuit power to about two and one-half times full-load power. This solved the problem for medium-sized stations. Thus in a 60,000-horse-power station, instead of a possible short-circuit power of over half a million horse-power, the power is limited to 150,000 horse-power.

However, even with generator reactances, with increasing size of station, the power which may be let loose under short circuit becomes large beyond control; with a 400,000-horse-power station, with generator power limiting reactances, a million horse-power may still be concentrated at a short circuit.

Busbar reactances then were introduced; that is, the busbars divided into sections by reactances sufficiently small not to interfere with the interchange of power along the busbars, and thereby retaining the advantage of parallel operation, but large enough to limit the flow of power, which, in case of a short circuit on one busbar section, can flow into it from the adjoining sections.

By such reactances in the busbars and in the tie feeders be-

tween the stations, the system is divided into sections of about 60,000 horse-power each. A short circuit then can seriously involve one busbar section only, and the destructive power of a short circuit is limited to that of one section, plus the limited power which can flow from the two adjoining sections, a total of 150,000 to 200,000 horse-power, and this is within the emergency limit of the modern oil circuit breaker of moderate size. It still represents a terrific energy, nearly 10,000,000 foot-pounds, and is a severe strain on the circuit breaker.

These busbar reactances permit an unlimited extension of the system, and the short circuit on a section of a half-million-horse-power system is no more severe than a short circuit on a 100,000-horse-power system, and there is now no limitation to the future increase to electric systems of many millions of horse-power capacity, operating in parallel on one set of busbars.

With hundreds of feeders radiating from the busbars, the probability of a short circuit in feeders is far greater than in the busbars, and a material advantage, therefore, is given by *feeder reactances;* that is, reactance interposed between the feeder or a group of feeders and the busbars, so that a short circuit in the feeder is still more limited than a short circuit in the busbars.

By the development of generator reactances, busbar reactances, and feeder reactance, the problem of the power control of large systems for protection against self-destruction by short circuit has been solved and unlimited extension of systems without any increase of danger has been made possible, and experience has shown that after the introduction of such power-limiting reactances dead short circuits have occurred at the busbars of very large systems without even interfering with the operation of most of the synchronous apparatus on the system.

Not all three classes of reactances are always necessary: in systems of moderate size busbar reactances may not yet be needed. In low-head water-power plants, with slow-speed multipolar alternators of inherently limited short-circuit current, generator reactances may be unnecessary and only busbar reactances required. Such, for instance, is the case at the Keokuk plant on the Mississippi River. Again, with a perfect system of generator and busbar reactances, feeder reactances may be dispensed with—though they are even then an advantage.

In high-voltage transmission networks, even of very high

power, power-limiting reactances sometimes may not be required or less essential. With a considerable number of medium-sized water-power plants feeding into a transmission system, the power of each individual generating station may not be sufficient to give destructive values under short circuit, and the impedance of the lines between the generating stations may be sufficient to limit the power which can feed into the short circuit at one station. In transmission networks, therefore, power-limiting reactances are necessary only in very large generating stations, as the Keokuk station, or where several fairly large stations are close together, and also, as generator reactances, in turbo-alternators connected into the system as steam reserve.

To cut off a disabled line or feeder with the voltages and powers of our modern systems is beyond the capacity of the fuse or simple blade switch, and automatic oil circuit breakers are generally used. However, the problem has become more difficult by the increasing demand for reliability and continuity of service.

The two main sources of troubles in lines and cables are *grounds* and *short circuits* between phases. In transmission lines a ground on one phase is the most frequent trouble, and short circuits are rare except in lines in which the design was faulty, or reliability had been sacrificed to cheapness, and the spacing between conductors chosen too small, so that they swing together during wind storms, etc. A short circuit is far more serious than a ground, as in the former the current is limited only by the generator capacity, while with a ground the current has no return—except if the neutral is grounded, and then over the resistance of the neutral—and the current, and with it the shock on the system, therefore is very much less, especially if safeguards against the occurrence of high frequency by *arcing grounds* are installed. In a well-designed transmission line a short circuit usually occurs only as the result of two simultaneous grounds. A ground on one conductor, however, raises the voltage against ground, of the other two phases, from the Y voltage to the delta voltage of the system, and thereby increases the strain on the insulation of the other two phases. It thus either introduces the danger of a second ground, causing a short circuit, or requires a higher grade of insulation.

This has led to two methods of operation of transmission systems. Either the neutral of the transformers is grounded,

frequently through a resistance, where the resistance of the ground is not high enough to limit the current. Then a ground on one phase is a partial short circuit to the neutral, causes a large current to flow, and thereby opens the automatic circuit breakers and cuts off the circuit before the ground has developed to a short circuit. However, this method, the "*grounded Y system,*" means a shutdown at every ground, every flashover of an insulator by lightning, etc. Or the neutral of the system is not grounded, the insulation of the circuit made good enough to safely stand the increased strain put on it by a ground on one phase, and by an *arcing ground suppressor,* etc., care taken not to continue an arcing ground—leading to high-frequency disturbances—but convert it into a metallic ground. In this case, the "*isolated delta*" *system,* service can be maintained on the circuit, even if one phase grounds, until arrangements are made to take care of the load, or the fault found and remedied, and the continuity of service thus is not interfered with. However, the cost of line construction is higher, due to the better insulation required. The relation between grounded Y and isolated delta thus is that of cheapness *versus* reliability and continuity of operation, and, as a rule, we find grounded Y systems where lowest cost of development is considered essential and occasional interruption of service not considered objectionable, while the isolated delta is generally preferred in systems in which reliability and continuity of service are considered as of first importance, such as in the extension across the country of the great Metropolitan Edison Systems—systems which are proud of their record that the voltage has not been off their busbars for ten years or more.

Different are the conditions in underground cable systems. In a cable the three conductors are so close together that a ground on one conductor quickly reaches the other conductors and becomes a short circuit. A grounded cable, therefore, cannot be kept in service, but has to be cut out as promptly as possible. In these systems it therefore is customary to ground the neutral through a resistance sufficiently low, in case of a ground on one conductor of a cable, to allow sufficient current to flow to open the circuit breaker and cut off the cable, but sufficiently high not to give a severe shock on the system. Or, where grounding of the neutral is considered undesirable, an arrangement of relays is made to give the same effect. With underground cables such

cutting off of a disabled feeder does not interfere with the continuity of service, as a number of feeder cables are always used in multiple for every important substation.

However, the problem of cutting off a disabled feeder by the operation of the circuit breaker, due to the large current taken by the grounded feeder, is not so simple. Assuming that three cables feed in multiple into a substation, and one of these feeders grounds: a large current then flows from the generating station into this cable to ground, and the circuit breaker at the generator end of this feeder opens. This, however, does not stop the current rush, but a large current still flows through the damaged cables into the ground, coming back from the substation, and flows to the substation from the generating station through the two parallel feeders, which are undamaged; that is, short-circuit current feeds back through these two cables over the substation, and these two cables also open their overload circuit breakers, cutting off and thereby shutting down the substation. If the substation is connected by tie feeders to adjoining substations, current feeds back into the faulty cable over these tie feeders from adjoining substations, and these tie feeders, and the cables feeding the adjoining substations from the generating station, open their circuit breakers by overload, and in this manner a ground in one cable may shut down a number of substations, possibly the entire system. *Time-limit devices* in the circuit breakers are insufficient to protect against such extended shutdowns resulting from a single fault in a cable. A permanent time limit is not permissible in large systems, as with a dead short circuit the circuit breakers must open instantly before extensive damage is done by the large power of the short circuit. Therefore so-called *"inverse time-limit"* circuit breakers are generally used; that is, circuit breakers in which the time limit of their operation decreases with increasing overload. Such circuit breakers would first cut off the cable carrying the greatest excess current,—that is, the faulty cable,—and then those of less excess current; but, as with the cutting off of the faulty cable—at both ends—the excess current stops, other cables should not be interfered with. However, the inverse time-limit circuit breaker necessarily must be practically instantaneous under short circuit, and therefore, while the time limit discriminates between 100 per cent. or 200 per cent. or 300 per cent. overload, it cannot discriminate between

short circuits of various severity; that is, not only the faulty cable, but its parallel undamaged cable, and the tie cables to other substations, etc., would open, and, while the extent of the shutdown would be somewhat limited, it is still far beyond the extent permitted by reliability of service.

Thus devices become necessary to select a disabled feeder and cut it out without cutting off its parallel feeders or the tie feeders to the substation served by the faulty feeder, regardless of what excess currents these may carry. This is a problem which has not yet been completely solved.

As the result, in general in high-power systems of high standard of reliability the radial system of substation supply is used; that is, each substation is fed by a separate set of cables, and the substations are not interconnected into a network by a system of tie feeders. This radial system, however, is materially less economical in feeder copper than the interconnected network, since the radial system requires for each substation a feeder capacity equal to the maximum power demand of the individual substation, while in the network, by cross-feeding between the substations, the feeder capacity is reduced to that required by the average maximum demand of the substations.

To avoid a shutdown of the substation by a fault in one of its feeders, the different feeders of the same substation are not connected in parallel in the substation, but feed separate translating devices, as transformers and converters, and are paralleled in the substation only on the secondary side of transformer or converter. In case of a faulty feeder, the current feeding back into the fault over the other feeders of the same substation, therefore, has to pass through two sets of translating devices, and this limits it sufficiently to allow the time limit relay of the circuit breakers to operate and cut out the faulty feeder without opening the other feeders; that is, without shutting down the substation.

However, the economic disadvantage of the radical system remains, and an effective *selective feeder relay*, which could be relied upon to pick out the faulty feeder and no other, would offer material advantages.

Such a selective device is afforded by the use of *pilot cables*. Each cable or feeder is duplicated by a smaller low-voltage, three-phase cable, which joins the secondaries of current transformers connected into the two ends of the main cable. If the main cable

is undamaged, the same current comes out of it as flows into it, and the connections to the pilot cable are such that in this case the secondary currents would be in opposition; that is, neutralize each other. If, however, the main cable grounds, current flows into it from both sides, the secondary currents in the pilot cable then add, and the current flowing in the pilot cable operates the relay which opens the circuit breaker. This arrangement is very perfect in operation, capable of cutting out the damaged cable, whether feeder cable or tie cable, without interfering with any other cable, but it has the formidable disadvantage of doubling the number of cables required in the system, and, while the pilot cables are small and of low voltage, they occupy room in the underground ducts which carry the electric circuits in American cities. Thus this method of control by pilot cable is, due to its high cost of installation, very little used in this country.

Another method is that of the "*split conductor*" cable. Every cable conductor is made of two parts, of which the one surrounds the other concentrically, with some insulation between them. Normally there is no potential difference between the inner and the outer half of the conductor, as they are connected with each other at the ends of the cable. If, however, a ground occurs on the cable, this ground can at first reach only the outer half of the conductor, and a potential difference and current appears between the inner and outer half of the conductor and operates the circuit breakers, through a relay connected between the two halves of the conductor, at either end of the cable.

This method also works very satisfactorily, but has the same economic disadvantage, though to a lesser degree than the method of pilot cables, in that the split conductor cable is materially larger and more expensive than the standard cable. It is therefore used to a limited extent only.

The usual method of taking care of the problem, at least in most cases, is by the so-called "*reverse power relay*," also wrongly called "reverse current relay."

When a cable grounds, the current at its end reverses; that is, flows into the cable ("feeding back") instead of coming out of it. However, this reversal of current by itself can do nothing, as it is an alternating current, and as such has no direction of its own, but only a relative direction to other alternating waves, as that of the voltage. Installing then a wattmeter relay at the end

of the cable,—that is, a relay operated by the action of two coils upon each other, the one coil energized by the current, the other by the voltage: if the current reverses, the voltage remaining the same, the pull of the relay reverses, and thereby closes the operating circuit, which opens the circuit breaker which disconnects the cable.

Such reverse power relay operates perfectly so long as there is any voltage for the reverse current to act upon. If, however, a short circuit occurs at or close to the substation, the voltage vanishes, and with it the reverse power relay looses its pull. To guard against this, the installation of reactances is recommended between cables and substations to give a sufficient voltage drop to operate the relay. However, this is an additional complication.

The reverse power relay is not adapted to guard tie feeders between stations, as in these the current reverses in direction with the change of the distribution of load between the substations.

Thus the reverse power relay does not make the operation of interconnected networks of substations possible, but in the radial system of operation, which is generally used, it is the only device which is generally available economically, and is very satisfactory, with the only exception—which must be realized—that it cannot operate where there is no voltage left.

In overhead transmission systems and networks the problems of selectivity are essentially the same as in underground cable systems, except that in interconnected networks of distributed generating power the high impedance of the lines often gives an automatic partial selectivity, which cannot exist with the low impedance of cable systems.

Interference by *lightning,* with high-potential transmission lines, has rather decreased with increasing line voltage, and this is very fortunate when considering the enormous extent of these systems and the resulting certainty of lightning effects. In the present high-potential transmission lines voltages have been reached comparable with the voltage of lightning disturbances; possibly not with the voltage of the direct lightning stroke—but direct strokes into lines are rare—but few lightning-induced voltages reach beyond the insulation strength of modern high-voltage lines. In 100,000-volt lines the insulators are tested for one minute at 200,000 to 250,000 volts, and stand momentarily, for the very short time of lightning, over half a million volts.

Thus it is rare that lightning flashes over or punctures the suspension insulators of our very high-voltage transmission systems. A flashover, with the grounded Y system, shuts down the circuit, often without any damage, while with the isolated delta system it may not even shut down the circuit, but is taken care of by the protective device against flashovers, the arcing ground suppressor in the station. Most lightning voltages incapable of destroying the line insulation run along the line until their energy is dissipated or they reach a station, and there they often do serious damage. The most important problem of lightning protection thus has become the rapid damping out of line disturbances caused by lightning, so as to make them harmless before they reach the station. The most effective method heretofore is the overhead ground wire. By its screening effect it lowers the voltage which lightning can induce in the line, but far more important is its powerful damping effect on the line disturbance, the travelling wave caused by lightning, which runs towards the station. As short-circuited secondary to the line wire, the ground wire absorbs and dissipates in its resistance the energy of the travelling wave, and causes it to die out at a rate several times more rapid than is the case in a line which is not protected by ground wire.

Far more destructive than the energy of lightning may be the *internal energy* of the system. While a lightning stroke may amount to millions of horse-power, at a duration of a millionth of a second, this means only thousands of foot-pounds. In a transmission network of thousands of miles extent a surge of the system may amount to many thousands of horse-power. But even a surge of a hundred horse-power only is liable to be very destructive, as it may be continual, the generator power continually replenishing the surge energy, and a hundred horse-power, during one hour, means 200,000,000 foot-pounds.

Thus the foremost problem is again the protection of the system against destruction by its internal energy, and lightning is dangerous mainly by letting loose the internal energy.

Against damage by breakdown to ground, by overvoltages, effective and complete protection is given by the *aluminum cell lightning arrester,* so that the problem of overvoltage protection resolves into the economic question, how far the cost of lightning

arresters is warranted by the elimination of the danger of breakdown to ground.

Impulses, high-frequency oscillations, and stationary waves are the most common other dangers.

An *impulse* is an electrical effect in which voltage and current rise rapidly—with a "steep wave front"—and then gradually taper down and die out. Such impulses are produced by switching operation, by flash over the insulators, by induction from lightning flashes, etc. The danger from impulse voltages lies in the local piling up of voltage due to its steep wave front. Thus, for instance, when a switch is closed and 100,000 volts put onto a line at the moment of closing the switch, 100,000 volts suddenly appear in the line at the switch, while perhaps five feet away the line voltage is still zero. Gradually—with the velocity of light, or 188,000 miles per second—the voltage spreads over the line as an impulse. Suppose now such impulse reaches the terminals of a transformer near the source of the impulse, where its wave front is still very steep. When the full impulse voltage reaches the first transformer turn the second transformer turn is still at zero voltage, and the full voltage of 100,000 comes on the insulation between the first two turns. While the transformer winding is insulated to stand 200,000 volts to ground for one minute, and momentarily still much higher voltage, normally the voltage between adjacent turns may be only ten volts, and with all the extra insulation between the end turns, even if we make this insulation to stand 1000 times the voltage to which it is normally exposed, it would be far below standing 100,000 volts. Thus the danger from impulses is that they produce voltages across small parts of the circuit, single turns or coils, which are often many thousand times the normal voltage existing in this part of the circuit; thus they may be far below the total circuit voltage, and thus would not discharge over the overvoltage protective devices or "lightning arresters."

Fortunately such steep waves fronts rapidly flatten out in the progress of the wave along the circuit, so that their danger is largely limited to the immediate neighborhood of the origin of the impulse.

Assuming now that we would, by a condenser in shunt to the circuit, bypass the energy of the impulse for only one-millionth of a second. During one-millionth of a second the impulse travels

about 1000 feet, and such a very small condenser would flatten the wave front to 1000 feet length. With such a flattened wave of 1000 feet front, before full voltage appears at the transformer terminals, the beginning of the impulse is passed over ten or more turns, and the impulse voltage thus distributes over the insulation of a number of turns, and no difficulty exists to give the end turns an extra insulation sufficient to stand the voltage.

The foremost cases of high-frequency oscillations are spark discharges from the line, arcing grounds, etc. Their danger also is the piling up of voltage in reactive devices, such as current transformers, end turns of power transformers, etc. While a current transformer may take only a few volts at the normal frequency of sixty cycles, at 10,000 times this frequency it would take 10,000 times the voltage, and then break down between turns and between terminals. Inductance to reflect the high-frequency oscillation back into the line—which can stand it—with shunted capacity, and a non-inductive or, preferably, a capacity bipath to the inductive device such as the aluminum cell, offers protection against the danger from high-frequency oscillations. The best guard against interference by high-frequency oscillations is, however, to avoid all causes which may produce them, and the foremost cause is the arc. Thus arcs, arcing grounds, spark discharges, open-air switches, etc., should be carefully avoided in transmission systems, as introducing the dangers of high-frequency disturbances. This is to a large extent a designing problem.

In apparatus capable of electric oscillation,—that is, apparatus of high inductance, considerable capacity, but very low energy losses, such as high-potential transformer windings,—under certain conditions *stationary waves* may occur; that is, high-frequency impulses or oscillations, coming from the outside, built up by resonance to higher and higher voltages. Such stationary high-frequency waves are extremely destructive, as their energy is practically unlimited; is given by the low-frequency power of the system. Their frequencies usually are fairly low, between 10,000 and 100,000 cycles, and therefore it is more difficult to deal with them than with the oscillations of many hundred thousands or millions of cycles.

The best protection against them is not to allow them to build up. This is done by designing the apparatus so as to give the

least ability to stationary oscillations, and by dissipating their energy, and thereby limiting their voltage, by shunted resistance. To avoid the excessive waste of power in such shunted dissipating resistances, a condenser of moderate capacity is connected in series with them. Such condenser practically cuts off the flow of power at the low machine frequency, but permits the flow of large currents through them into the dissipating resistance at the much higher frequencies of the standing waves.

In considering the protection of modern electrical systems it must be realized that the various sources and kinds of interference or danger require correspondingly different protective devices: it would be just as unreasonable to expect a standard type of "lightning arrester" to protect an electric system against all possible troubles as it would be to call for a single-standard "safety device" which would protect a railway train against all possible dangers, from a broken rail or a washout of the roadbed to a collision or a boiler explosion.

The Use of Copper Sulphate in the Purification of Swimming Pools. STANLEY JUDSON THOMAS. (*Journal of Industrial Chemistry*, vol. 7, No. 6.)—Within the past two or three years numerous articles have been written relating to the sanitary conditions of indoor swimming pools. One fact is emphasized by all authorities: that the danger of transmission of zymotic disease through the swimming pool is *real*. There is no doubt that hypochlorite of lime, which has been recommended as a precautionary treatment of public water supplies, is without a peer. It has been shown that 2.5 parts per million of hypochlorite of lime purifies the water shortly after its introduction into the pool, but it soon loses its germicidal properties. To add 2.5 parts per million of "hypochlorite" every day would probably solve the problem from a bacteriological standpoint, but the odor would be too offensive for this form of treatment to be considered. The idea was conceived and acted upon of using a small amount of copper sulphate. The result of using 0.4 part per million of copper sulphate proved very satisfactory. From a comparative study and tests of the two methods of sterilization, the advantages of copper sulphate over hypochlorite of lime may be summarized as follows: (1) It is more effective, because it does not undergo chemical change readily. (2) It is not irritating to the eyes and mucous membrane, as is "hypochlorite," if the latter is used in germicidal quantities. (3) It is cheaper. (4) It has no odor. If all other conditions were equal, this last fact alone would prove its great advantage over "hypochlorite."

BIOCHEMICAL AND ENGINEERING ASPECTS OF SANITARY WATER SUPPLY.*

BY

GEORGE W. FULLER, C.E.,

Consulting Hydraulic and Sanitary Engineer, New York, N. Y.
Member of the Institute.

THIS topic is a very broad one. In fact, some difficulty has been experienced in reaching a conclusion as to which particular aspects of this topic these remarks should be directed.

" Biochemical " is not a very precise term. It is used differently by different persons. It is proposed to-night to speak more particularly of the biological rather than the chemical phases of this broad field which deals with the sanitary features of public water supplies. Reference will be made especially to means of measuring the sanitary quality of water supply through biological methods, and then of the accomplishments upon the public health of modern engineering works to conserve or improve the quality of water. The engineering works themselves will be scarcely touched upon.

While the main theme of this talk will be means of measuring the sanitary quality of public water supplies, both through laboratory procedures and the study of vital statistics, attention will be directed to some striking instances where it is proved that public water supplies are not wholly to blame for the prevalence of diseases generally associated with the public water supply. Other sanitary conditions are involved, and, as our knowledge of vital statistics and of modes of transmission of disease becomes more complete, it is shown that the city sanitarians have duties to attend to which in earlier years were assumed to belong to those who had charge of public water supplies.

This is a particularly apt time at which to speak on this subject. During the past week the United States Treasury De-

* Based on a paper presented at the meeting of the Mechanical and Engineering Section held November 12, 1914. Manuscript received March 24, 1915.

partment has published a report of a Commission of Expert Sanitarians to specify bacteriological standards for drinking waters to be supplied to the public by common carriers in interstate commerce. That this task has not been an easy one is shown by the fact that it has required nearly two years of deliberations to formulate a six- or seven-page report.

Another feature of importance in the current developments of sanitary science on this side of the Atlantic is the work now being done by the International Joint Commission having control of the pollution of the boundary waters between this country and Canada. This has brought squarely to an issue the proposition of what is a reasonable load as regards pollution that modern water filters may be expected properly to carry. In populated regions surface waters of virgin purity are impossible. This does not mean, however, that pollution can not and should not be controlled within limits that will not prove overburdensome to those whose task it is to build and operate filters and other devices for the purification of public water supplies.

The Rivers Pollution Act of Great Britain, adopted in 1876, was so stringent that it had but comparatively little influence upon the public health, owing to the difficulty and great expense involved in adjusting to it. The Royal Commission on Sewage Disposal of Great Britain decided two years ago, after deliberating for more than a dozen years, that less stringent standards should be set up and that, furthermore, plans for completed works necessary for certain conditions might derive the benefit of "relaxation." By this is meant that local authorities in Great Britain are to-day not obliged, in many cases, to build complete sewage purification works, although plans are to be prepared with that ultimate end in view, and that the construction work to that end must proceed in pursuance of local conditions both as to availability of funds for such work and as to local sanitary needs.

Laboratory methods for measuring the sanitary quality of water date back more than thirty years. They are contemporaneous in point of dates with the formulation and general recognition of the germ theory of disease and the transmission by water carriage of a number of the well-known diseases, particularly those of the intestinal group. Laboratory data do not afford a particularly satisfactory means of measuring the

quality of water. They are simply a rough indicator, and the interpretation of the data seems to be positive and satisfactory only when they apply to a very good water or a very bad water. In the middle courses of the range of quality of water, laboratory data are to-day in need of further careful study, both as to methods in use and the interpretation of the results.

Following the Spanish-American war the sanitary world was shocked at the discovery of the extent to which disease was transmitted through the agency of flies and other insects. Those experiences were attained largely in the big army camps where the hygienic environment related more particularly to the conditions prevailing in rural rather than in urban communities. Gradually there has been determined the important fact that public water supplies are not in all cases responsible for the transmission of intestinal diseases to the extent which was hitherto thought to be the case. The recent evidence has been obtained for the most part in southern cities where the fly period is of longer duration than in the northern cities. In the latter, however, the fly period for quite a number of months each year has been a factor involving the public health to a degree much greater than has been recognized by the majority of sanitarians.

Some of the more important recent data will be shown with the aid of lantern slides to illustrate specifically these general remarks as to the need of more precise methods in the laboratory for the measurement of the sanitary quality of public water supplies; and, again, as to means of measurement of the effect of the public water supply upon the general health of the community through recognition of the influence of other aspects of municipal sanitation in bringing about high death-rates from so-called water-borne diseases, and in cases where the public water supplies are in no way at fault.

DETERMINATION OF SPECIFIC PATHOGENIC BACTERIA.

Infectious diseases, such as may be water-borne, require the presence in the water of an appreciable number of the particular pathogenic bacteria producing the disease. It follows very simply, as an academic proposition, that if a correct examination of the water can show that no such disease germs are present, the water is safe for domestic consumption, and is what is generally termed "a wholesome water." Unfortunately, such

direct determination can be made only with the greatest of difficulty, and the results of such correct determination have only a doubtful value. A certain number of the bacteria producing water-borne diseases, such as the typhoid bacillus and the cholera spirillum, have been successfully isolated and can occasionally be detected in a polluted water. Broadly speaking, however, it is not at all certain that such bacteria will be detected, even if they are present in a public water supply.

A few investigators, among whom may be particularly mentioned Dr. A. C. Houston, Director of Water Examinations, Metropolitan Water Board, London, have insisted that their methods of determination of these specific organisms are sufficiently accurate and reliable, so that tests made by them showing that these bacteria are not present are conclusive to them that there is no danger of such diseases being caused by the water. Most of the laboratory workers do not concur in this viewpoint. They assert that, while specific bacteria may often be isolated and shown to be present in the water, they are not at all willing to say, on the other hand, that the fact that they are unable to isolate this organism shows conclusively that they are not present. They believe that the methods used are sufficiently uncertain so that typhoid or cholera bacteria may be present and still not be detected.

There is one other important factor which must be considered. We do not know with exact certainty what diseases are disseminated by water. A certain number certainly can be attributed at times to a water supply. Others are uncertain. There may be still others which may be carried by water, but we are not fully aware that they can be so carried. To make satisfactory tests of a water supply, therefore, by the direct method, would require specific tests for each particular type of pathogenic bacteria which we know can be carried by water or which possibly might be carried by water. Quite apart from the accuracy and desirability of results of such methods, the work would probably become so laborious and time-consuming for practical use in ordinary water determinations that the method falls of itself as too unwieldy to be used.

In effect, any such direct meth[illegible] ideal as they may be, fail us in service, and we must have [illegible] course to some indirect

method which will give us better service. The indirect methods available are, first, the determination of the total number of bacteria present in a given volume of the water, and, second, the determination of the absence or quantitative presence of certain specific bacteria which may be called indicators of the possibility of the presence of disease germs.

SIGNIFICANCE OF TOTAL BACTERIAL COUNT.

The oldest and simplest biological method of gauging the quality of a water supply is by counting the total number of bacteria by means of the colonies formed by growth on some solid nutrient medium. The method formerly used and still in most general practice is to count the total number of colonies produced by incubation on solid gelatine in forty-eight hours at a temperature of 20° Centigrade, and to call this the number of bacteria present in the quantity of water examined (one cubic centimetre). By this standard, German sanitarians about twenty-five years ago fixed on one hundred bacteria per cubic centimetre as the fair dividing line between a good and an unsatisfactory water, under their local conditions as studied. Any water showing less than these one hundred bacteria per cubic centimetre was considered satisfactory, but a bacterial count in excess of this amount showed a water of inferior quality. This standard has been very much used and until fairly recent times has been considered a reasonable and proper standard for some classes of water.

A number of rather obvious objections present themselves to the use of this standard for determining the water quality. The first natural objection is that there may be, and probably is, no definite relationship between the number of bacteria present in the water and the number of pathogenic bacteria which may cause disease. The bacteria in the water originate from any number of points. They come from the soil, the vegetation, and from animals; they grow in the water itself, and many forms multiply very rapidly in the water. A pure water may show very high bacterial results, and a polluted water a relatively small bacterial count.

In considering any new source of water without knowing its special local conditions, it is almost impossible to say from

the total bacterial count alone whether the water is good or poor or something intermediate. It even happens that in carefully filtering water the filtered effluent may show as many as, or even more bacteria than, the water applied to the filters. This comes from the fact that certain species of bacteria may grow in the filter itself, particularly in its underdrains, and from this growth of water bacteria, always of a harmless form, the effluent obtains its large bacterial count. And yet this filtered effluent may be entirely free of any pathogenic forms.

Another factor militating against the useful purpose of this total bacterial count test is that the incubation was effected at a temperature of 20° Centigrade, about normal room temperature. Under such conditions the growth of the harmless water bacteria is facilitated, while the growth of the pathogenic bacteria, which naturally thrive at the body temperature, is partially inhibited. It has been attempted to meet this difficulty by specifying a different total bacterial count method of testing. This involves the incubation of the sample at a temperature of 37° Centigrade, using nutrient agar as the medium. The use of the high temperature, approximately that of the body, serves the purpose of encouraging the growth of various bacteria which thrive at the body temperature, and of inhibiting the growth of the ordinary non-pathogenic bacteria. This gives relatively small counts on the plate, but these bacteria, of smaller number, perhaps, may be a fairer measure of the possible presence of contaminating organisms.

Table I of "Comparison of Gelatine and Agar Counts for Various Coli Conditions" exhibits, opposite to each other, the bacterial counts per cubic centimetre obtained by the two methods above cited. It will be seen that the bacteria shown by the 37° agar test are very much lower than those shown by the 20° gelatine test. There is, however, no constant relation between the two. In some cases the agar may show only ten per cent. of the bacteria of the gelatine test. In other cases the count may be twenty-five per cent. or more of those shown by the gelatine test. It is, of course, not to be expected that there should be any constant relation, or even approximately constant relation, between these two tests. In addition, different waters and different conditions of the same water, even different seasons of the year will show a different relation in the count by the two tests.

TABLE I.

COMPARISON OF GELATINE AND AGAR COUNTS PER CUBIC CENTIMETRE FOR VARIOUS COLI CONDITIONS.

Counts shown here are the average for sixteen months

B. coli	Class A water			Class B water			Class C water			Class D water		
	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar	No. of Samples	Gelatine	Agar
Negative in 10 c.c.	...	.....	.....	...	.....	.....	113	920	30	352	44	8
Positive in 10 c.c..	...	.....	.....	...	.....	.....	194	1075	43	75	571	29
Negative in 1 c.c..	14	4741	367	36	9313	845	...	...	...	...	...	...
Positive in 1 c.c...	52	46590	3386	113	42982	5420	71	1655	56	11	715	16
Positive in $\frac{1}{10}$ c.c..	102	45511	11728	166	35641	6443	13	3297	26	...	...	...
Positive in $\frac{1}{100}$ c.c..	94	37762	11177	143	33106	6345	...	...	...	...	...	...
Positive in $\frac{1}{1000}$ c.c..	93	35677	9129	101	31727	6821	...	...	...	...	...	...
Positive in $\frac{1}{10000}$ c.c..	104	49175	19393	56	38632	11680	...	...	...	...	...	...
Total samples...	459	.....	.....	615	.....	.....	391	...	...	438	...	...

Reference—W. U. C. Baton, Journal Am. W. W. Assn., 1914, Vol. No. 1—p. 19.

An instructive series of investigation has recently been made by Dr. Ernst Quantz, at Göttingen, in Germany, and published in the *Zeitschrift für Hygiene*, 1914, vol. 78, p. 193. Table II shows the results of this investigation made entirely with various well waters. The well waters are divided by the author into three classes: Group I, as shown in the table, consists of wells which are practically impossible for pollution, and may be considered as safely good well waters. Group II are rather doubtful, and at times might possibly be polluted and at other times be pure. Group III are those classed by the author as particularly bad wells, and pretty nearly certain to be polluted.

TABLE II.

BACTERIAL COUNT OF WELL WATERS.

By Dr. Ernst. Quantz—Zeit. f. Hyg.—Vol. 78—Page 193.

Bacterial count per cubic centimetre	Number of examinations			Per cent. of examined wells		
	Group I	Group II	Group III	Group I Good	Group II Doubtful	Group III Bad
0— 10	2	0	0	6	0	0
11— 50	5	10	0	16	9	0
51— 100	3	10	0	9	9	0
101— 200	6	12	1	19	10	3
201— 500	6	22	4	19	19	11
501— 1000	6	18	7	19	15	20
1001— 2000	3	18	7	9	15	20
2001— 5000	1	13	5	3	11	14
5001—10000	0	11	3	0	9	9
10001—20000	0	1	5	0	1	14
Over—20000	0	2	3	0	2	9

In examining these data a very general relationship is shown. Thus, taking 1000 bacteria per cubic centimetre as the limit, we see in Group I that 88 per cent. are under this limit; in Group II, 62 per cent.; and in Group III, 34 per cent. Taking 100 bacteria as the limit, in Group I, 31 per cent. are under this limit; in Group II, 18 per cent.; and in Group III, no per cent. This indicates very fairly that better wells, on an average, have a lower bacterial count than the poorer wells. The author's bacterial count was taken on gelatine at 20° Centigrade.

Individual wells, however, show no such relationship. In some cases good wells show a higher bacterial count than poor wells. Very often the rate of draft on the wells is a bigger factor in the number of bacteria shown than the possibility of pollution. Good wells which have been standing for some time show a very high bacterial count.

The most that can be deduced is that very low counts mean certainly very safe water and very high ones possibly unsafe ones.

As the conclusion of some thirty years of experience, bacterial counts are still taken as showing roughly the variation in the same water. In other words, their chief advantage is found in comparing a water before and after it is filtered. Especially is this true of counts on gelatine at 20° Centigrade.

When taken alone bacterial counts are not considered ordinarily as a reliable indicator of the safety of the water.

SIGNIFICANCE OF B. COLI AS AN INDICATOR OF POLLUTION.

After eliminating as a satisfactory indicator of pollution the total count of bacteria which may originate anywhere at all, the next natural step is to restrict our investigation to those particular bacteria which seem likely to originate in the human body. The normal rule seems to be that only human diseases are transmitted to other human beings, and that bacteria, in order to cause infection, must originate in man. Infectious pollution in water supplies arises almost wholly from discharges from the human intestines, and any bacteria which can be assumed to originate in the human intestines would be a fair measure of such human pollution which potentially might be dangerous or infectious.

Unfortunately, there are no such bacteria which are a positive indicator of human pollution. The nearest thing to it are the coli bacilli. Thus *B. coli* are always found in any discharges from the human intestines. They are also found, however, in the discharges from the intestines of animals, birds, fishes, and on cereals, grains and many other places. They are even found in the air, the dust, and, because of their widespread occurrence, have often been termed "ubiquitous." Because of these conditions it is not a simple matter to say that any water supply which shows the presence of *B. coli* necessarily possesses any specific danger of human pollution or of infection which might at any time have been present. It merely suggests a potential danger in such a water.

This difficulty is made more pronounced by the large number of forms or types in which the *B. coli* appear. The colon bacillus is not a simply definite form of unvarying properties. It represents, rather, a whole class or series of classes of bacteria resembling each other in a certain number of properties and differing in other properties. There is a graded series of bacteria, some of which have in common many qualities, but the extremes of the series have only a small number of things in common. Attempts have been made to divide these coli bacilli into two general classes, one called the typical coli and the other the atypical coli. The typical coli is the one which is most likely to occur in the human intestines, and the atypical coli is that form which is most likely to originate elsewhere.

In 1905 the Committee on Standard Methods of Water Analyses of the American Public Health Association, of which the speaker was a member, drew up a set of standard tests for *B. coli,* designed to distinguish the typical from the atypical form, and to rate only the typical form as *B. coli.*

More modern methods have shown the general tendency to make less difficult and more approximate tests of the occurrence of *B. coli.* They involve the use of the lactose peptone bile "presumptive test" as sufficient to show *B. coli* and to rate coli or coli gas-forming bacteria by this test. There is a good deal to be said for these simpler, speedier methods now used, even if they are not a positive guide for separating the percentage of *B. coli* which comes from the intestines of man, as distin-

guished from the bacteria reacting similarly in the laboratory and coming from the intestines of other domestic animals, grains, soils, etc.

The percentage of organisms of the coli group, rated as positive by the presumptive test that would be considered typical *B. coli* by confirmatory tests, varies from at least thirty to ninety per cent., according to various workers testing different waters. Quite possibly in some waters the percentage of *B. coli* of typical forms would be much less than this. It is to be understood that even with this small percentage of typical *B. coli* there is no evidence to show what portion, if any, of the *B. coli* originated in the intestines of man.

In Table III the relations of the *B. coli* result by different methods of testing are given. These figures by Professor Gärtner are taken from Dr. Houston's tests of London water. Three methods of testing are given: the first, the so-called presumptive test, is noted from the gas formation; the second column involves a so-called confirmatory test, as applied by Dr. Houston; and in the third column are given the results of so-called typical tests. Comparing the results given by the presumptive test and by the typical test for one cubic centimetre, we see that for the Thames raw water before storage the typical test showed almost as much coli as the presumptive test, or, in figures, about eighty per cent. as much. In the Lambeth Reservoir, after storage, the typical coli are only about fifty per cent. of those shown by the presumptive test. In the Chelsea Reservoir, after storage, the typical coli are shown to be only about forty per cent. as much as the presumptive coli. In the LaValle Reservoir, after storage, the typical coli are less than twenty per cent. of the presumptive coli.

Generally speaking, the raw water shows a higher percentage of typical coli, and storage waters, which are largely purified by long storage, show a smaller percentage of typical coli. This may be because some, even a large part, of the original coli lose their typical properties in age, as is often claimed to be the case. It may be because the typical coli are less long-lived than the atypical coli. It might also be inferred from this table that the typical coli are better indicators of the water quality than the atypical coli.

TABLE III.

RELATION OF B. COLI RESULTS BY DIFFERENT METHODS.
By A. Gärtner—Zeitschrift für Hygiene—1910, vol. lxvii, p. 55.

Source of water	Volume tested c.c.	Per cent. of tests showing positive results		
		Presumptive test	Confirmatory test	Typical test
		Fermentation and gas formation of bile, glucose and peptone solution	Isolation of coli-like microbe, forming gas either in glucose or lactose	Isolation of coli-like microbe, forming indol in peptone water and gas in lactose
Thames, raw water before storage	.0001			
	.001	3.4	3.4	
	.01	27.0	24.7	10.1
	.1	84.3	79.8	48.3
	1.	98.9	97.7	83.1
	10.	100.0	99.9	97.7
	100.	.....	.....	99.9
Lambeth Reservoir, after storage	.0001			
	.001			
	.01	1.2	1.2	
	.1	14.9	13.7	7.5
	1.	44.9	39.9	23.7
	10.	82.4	74.9	51.2
	100.	97.4	97.4	83.7
Chelsea Reservoir, after storage	.0001			
	.001			
	.01	1.1	1.1	1.1
	.1	4.5	4.5	3.3
	1.	30.3	22.4	13.4
	10.	65.1	49.3	32.5
	100.	85.3	74.0	57.2
Staines Reservoir, after storage	.0001			
	.001			
	.01			
	.1	3.6	1.2	
	1.	21.7	16.8	9.6
	10.	53.0	44.5	32.5
	100.	84.3	80.6	66.2
Lee River water, before storage	.0001	2.2	1.1	1.1
	.001	11.1	11.2	5.6
	.01	33.6	29.1	16.8
	.1	79.7	75.2	55.0
	1.	99.9	99.9	93.2
	10.	....	....	99.9
	100.			
LaValle Reservoir, after storage	.0001			
	.001			
	.01			
	.1	1.1		
	1.	5.6	2.2	1.1
	10.	16.8	11.1	5.6
	100.	55.0	44.8	32.5

Dr. Houston, in a recent report on the value of storage, points out that storage results in a devitalization of the undesirable bacteria, on account of the water being an unsuitable medium for sustaining their activities. He speaks of this as the "Glagesten" theory in the storage of impure water.

Coli tests should be used most cautiously in forming an opinion as to the quality of an untreated raw water. Such data should be weighed carefully in connection with a sanitary survey in the light of existing conditions as to the opportunity for pollution.

Realizing the inability to record the source of bacteria producing positive results by the coli tests, particularly as to whether or not they originated in the intestines of man, it is desirable to record what is available by way of information as to the relative prevalence in water of *B. coli* and *B. typhoid*. These results, so far as they have been studied, are quite erratic and unsatisfactory. We will make some mention of several comments, but before doing so it is desired to point out some of the irregularities known to the speaker due to changes in methods of determining *B. coli*, as follows:

In 1898 the speaker had charge of the testing station at the Cincinnati water works. The water was drawn from the intake at the old Front Street pumping station, adjoining the Pennsylvania Railroad train shed. Into the Ohio River above this intake there were emptied the contents of thirty-two city sewers, and six miles above the intake the Ohio also received the flow of the Little Miami River, draining a populous watershed. On the basis of the determinative tests made for *B. coli* then in vogue it was found that sixty per cent. of the samples showed the presence of this organism when one cubic centimetre of the water was tested. (See the speaker's report on Water Purification at Cincinnati, 1899, p. 40.)

In 1907 the intake was moved to the present site at California, seven miles above the old intake and one mile above the mouth of the Little Miami River. A marked falling off in the typhoid occurred during the summer of that year, and before the filtration plant was put in service in October of the same year. Since October, 1907, the city of Cincinnati has had one of the very lowest typhoid fever death-rates of any American city. By the present method of making the presumptive tests on the untreated Ohio River water at the upper intake now in use a positive result in one cubic centimetre samples is reported in eighty-five or ninety per cent. of the daily samples tested. No increase in population in Pittsburgh or other cities above can possibly explain

the change in analytical data as compared with those obtained in 1898.

At New Orleans, during the operation of the water testing station, Mr. R. S. Weston found in 1901–1902 that out of one hundred tests for *B. coli* he obtained positive results only three times when using from one to three hundred cubic centimetres of water per sample. (See Report on Water Purification Investigation, New Orleans, 1903, p. 47.)

By the presumptive method as now practised positive *B. coli* results are obtained in eighty per cent. or more of the one cubic centimetre samples. The present intake is above the city limits, and there has been no striking increase in the population of the cities of the Mississippi valley sewering into this river of great size. The cities of Baton Rouge and Vicksburg have more extensive sewerage than a dozen years ago, but their effect upon pollution at New Orleans can scarcely be measurable.

INTERNATIONAL JOINT COMMISSION STANDARD.

During the course of this last year an International Joint Commission, consisting of members appointed by the United States and by Canada, have been considering the question of the allowable pollution in international boundary waters. The particular features they were studying were to what extent sewage and other polluting discharges into these boundary waters should be reduced in amount and purified, and to what point these boundary waters might be allowed to be polluted and yet at the same time not occasion, in connection with water purification plants, any menace to public health.

In the course of this investigation this International Joint Commission obtained testimony from a number of sanitary engineers, and formulated a tentative standard of purity for these international boundary waters with respect to the proposition of not overloading water filters.

The problem here was not the one of determining what coli count was permissible for a drinking water. That problem, indeed, could not have readily permitted a general solution in the light of our present knowledge. The conditions of such surface waters as form the international boundary waters are such that safety demands that all of these waters be properly filtered before being used as domestic supplies. The problem,

then, relates to the extent of pollution permissible and still not make the waters unsafe after reasonable filtration. Giving proper weight to the effective work that can be expected of modern water filters, it is not necessary to specify a very rigid or exatcing standard for the raw water subjected to filtration. An approximate figure, which will reveal a water not extremely polluted, will be satisfactory. On this basis the speaker and his colleagues before the commission fixed a standard for a yearly average by the presumptive method, reasonably checked by confirmatory tests, of testing coli whereby positive results in 0.1 cubic centimetre samples of water should not occur in more than fifty per cent. of the samples. Averaging this in an arithmetical way, it would mean that there would be not more than about 500 *B. coli* in each 100 cubic centimetres of water. It is, of course, to be understood that such arithmetical averaging is not exactly possible, and the results will not correspond in taking one 100 cubic centimetre sample and in taking one hundred 1 cubic centimetre samples, or one thousand 0.1 cubic centimetre samples.

It is not to be assumed, on this basis, that it is impossible to filter properly a water in which the coli content is in excess of the amount here specified. A water may indeed show a much higher coli content and yet be filtered and sterilized after filtration, so that the resulting effluent will be highly satisfactory for all domestic consumption. Nevertheless, there is a good deal of question, as a matter of broad sanitary policy, whether water which is later to be used for drinking should regularly be allowed to become polluted at the intake to a water supply plant in excess of the amount specified. This standard, indeed, is reasonably liberal, and only unusual conditions will make necessary any very expensive purification of sewage wastes in order to keep water for filtration within the limits of this standard.

Table IV shows *B. coli* content in various water supplies. The results shown here are given on the basis of coli content in one cubic centimetre and in nearly all cases the coli bacilli occur only part of the time in the one cubic centimetre test. In the case of the Lawrence, Mass., water taken from the Merrimac River, and of the Albany, N. Y., water taken from the Hudson River, coli are to be found in 100 per cent. of the tests of the water, and, while the data are not shown in this table, the water roughly approximates to that of the standard tests. Experience has shown, too, that

these waters, which are the worst permissible by this standard for filtration purposes, are satisfactorily filtered by the Lawrence and Albany filters, and that the resulting effluent is reasonably satisfactory bacterially for drinking purposes.

TABLE IV.

OCCURRENCE OF B. COLI IN WATER SUPPLIES.

City	Source of supply	Year	Per cent. positive of B. coli in 1 c.c.			
			Raw water	Treated water	Kind of treatment	Presumptive test
Birmingham, Ala.	Five Mile Creek	1910	84.0	8.3	Filtered	Yes
Birmingham, Ala.	Five Mile Creek	1911	78.0	9.7	Filtered	Yes
Birmingham, Ala.	Five Mile Creek	1912	89.0	5.7	Filtered and partly sterilized	Yes
Birmingham, Ala.	Five Mile Creek	1913	78.0	0.0	Filtered and partly sterilized	Yes
Lawrence, Mass.	Merrimac River	1910	100.0	7.8	Filtered	No
Lawrence, Mass.	Merrimac River	1911	100.0	8.4	Filtered	No
Lawrence, Mass.	Merrimac River	1912	100.0	16.9	Filtered	No
New York City	Croton Lake, head	1911	65.0	....	.....	Yes
New York City	Croton Lake, dam	1911	21.0	....	.....	Yes
New York City	Croton Lake, head	1912	42.0	....	.....	Yes
New York City	Croton Lake, dam	1912	35.0	....	.....	Yes
New York City	Croton Lake, 135th street	1911	....	29.8	Sterilization	Yes
New York City	Croton Lake	1912	....	10.0	Sterilization	Yes
Philadelphia, Pa.	Torresdale supply	1912	....	4.1	Filtered and partly sterilized	Yes
Little Falls, N. J.	Passaic River	'11–'12	89.0	6.1	Filtered and partly sterilized	Yes
Washington, D. C.	Potomac River	1910	26.9	0.0	Filtered	No
Washington, D. C.	Potomac River	1911	16.9	0.8	Filtered	No
Washington, D. C.	Potomac River	1912	43.5	0.0	Filtered	No
Washington, D. C.	Potomac River	1913	45.5	....	.....	No
Harrisburg, Pa.	Susquehanna R.	1910	55.0	0.17	Filtered and sterilized	Yes
Harrisburg, Pa.	Susquehanna R.	1911	77.0	0.61	Filtered and sterilized	Yes
Harrisburg, Pa.	Susquehanna R.	1912	47.0	0.81	Filtered and sterilized	Yes
Clarksburg, W. Va.	Monongahela R.	'11–'12	....	0.3	Filtered and sterilized	Yes
Clarksburg, W. Va.	Monongahela R.	'12–'13	67.0	....	.....	Yes
New Orleans, La.	Mississippi River	1913	39.0	3.1	Filtered	Yes
Columbus, Ohio	Scioto River	1913	69.0	0.5	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1910	91.0	0.8	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1911	85.0	5.2	Filtered and sterilized	Yes
Cincinnati, Ohio	Ohio River	1912	93.0	3.0	Filtered and sterilized	Yes
Cleveland, Ohio	Lake Erie	1911	11.1	0.0	Sterilized	Yes
Albany, N. Y.	Hudson River	1912	100.0	5.0	Filtered	Yes
Wilmington, Del.	Brandywine Cr.	1911	99.3	....	.....	Yes
Wilmington, Del.	Brandywine, Cr.	1912	99.2	11.2	Filtered	Yes
Bangor, Maine	Penobscot River	1913	86.0	0.89	Filtered and sterilized	Yes
London	Thames River	1911	87.9	....	Filtered	No
London	Lee River	1911	86.7	....	Filtered	No
London	Chelsea stored	....	13.4	....	Filtered	No

In view of the importance of the pending investigations into the control of the pollution of the boundary waters between the

United States and Canada, it will not be out of place to include here the guiding principles put before the commission by the sanitary engineers whom they consulted, as follows:

"New York, June 27, 1914.

"To the International Joint Commission.

"Gentlemen: The following statements represent the essence of the opinions given by us before your honorable commission at the conference held in New York on May 26 and 27, 1914:

"1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns, are unsafe for use without purification, but are safe for use if purified.

"2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and, further, provided that the plant is properly operated.

"3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter, the best index of pollution now available for the purpose of ascertaining whether a water-purification plant is overloaded is the number of *B. coli* per 100 cubic centimetres of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout the year.

"4. While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimetres, or if in 0.1 cubic centimetre samples of the water *B. coli* is found fifty per cent. of the time. With such a limit the number of *B. coli* would be less than the figure given during a

part of the year and would be exceeded during some periods.

"5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource, and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

"6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

"7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

"8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth-inch mesh or by sedimentation.

"9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration, and treatment by sprinkling filters, contact beds, and the like, are unnecessary, inasmuch as ample dilution in the lakes and large streams

will provide sufficient oxygen for the ultimate destruction of the organic matter.

"10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

"11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

"12. The bacteriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the water be used without purification as sources of public water supply or should they be used for drinking purposes by persons travelling in boats.

"13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately from the waters traversed, unless subjected to adequate purification, but should be obtained preferably from safe sources of supply at the terminals.

"14. While recognizing that the direct discharge of fecal matter from boats into the boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter from vessels into the boundary waters should not be permitted.

"Yours respectfully,

"GEORGE W. FULLER,
EARLE B. PHELPS,
GEORGE C. WHIPPLE,
W. S. LEA,
T. J. LAFRENIERE."

Mr. F. A. Dallyn, who was one of the six consulting engineers to advise the commission, presented a minority report, in which he eliminated Paragraphs 5, 7, and 11, and made a few slight changes in some of the other paragraphs.

BACTERIOLOGICAL STANDARD FOR DRINKING WATER ADOPTED BY THE TREASURY DEPARTMENT FOR WATER SUPPLIED TO THE PUBLIC BY COMMON CARRIERS IN INTERSTATE COMMERCE.

On October 21, 1914, the Treasury Department adopted the standard for interstate carriers for water supplies for public drinking purposes in accordance with the recommendations by a commission appointed by the Secretary of the Treasury, January 22, 1913. This commission of fifteen sanitarians recommended a standard published in the United States Public Health Reports, vol. 29, No. 45, p. 2960, dated November 6, 1914, as follows:

> "1. The total number of bacteria developing on standard agar plates incubated twenty-four hours at 37° Centigrade shall not exceed 100 per cubic centimetre: *Provided* that the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.
>
> "2. Not more than one out of five 10 cubic centimetre portions of any sample examined shall show the presence of organisms of the bacillus coli group when tested as follows:
>
> "(*a*) Five 10 cubic centimetre portions of each sample tested shall be planted, each in a fermentation tube containing not less than 30 cubic centimetres of lactose peptone broth. These shall be incubated forty-eight hours at 37° Centigrade and observed to note their formation.
>
> "(*b*) From each tube showing that more than five per cent. of the coli are in the fermentation tube, plates shall be made after forty-eight hours' incubation upon liquid lactose litmus agar or endo media.
>
> "(*c*) When plate colonies resembling *B. coli* develop upon either of these plate media within twenty-four hours, a well-isolated characteristic colony shall

be fished and transplanted into a lactose broth fermentation tube which shall be incubated at 37° Centigrade for forty-eight hours.

"Examining this above recommended standard, it will be noted that, roughly proportioning, twenty per cent. of the 10 cubic centimetre samples will be permitted to give positive indications of *B. coli*. These tests, however, are not to secure presumptive tests of the lactose peptone bile gas formation method; they are something nearer to the typical coli test. Accordingly the number of samples showing *B. coli* by presumptive tests may well run to forty per cent. of the 10 cubic centimetre samples. Comparing this forty per cent. standard, we note that the New York drinking water, as supplied in the 135th Street gate-house, showed a yearly average, in 1912, of forty-four per cent. positive results in 10 cubic centimetre samples, and in 1911 an average of seventy-six per cent. positive results.

"Assuming that water with forty per cent. positive results corresponds with the recommendations of the committee, the efficiency of the filtration and sterilization system, when compared with the permissible limits in raw water for filtration purposes as recommended by the International Joint Commission's sanitary experts, ought to correspond roughly to ninety-nine per cent."

The Treasury Commission state further as quoted herein:

"The bacteria developing on standard gelatine at 20° Centigrade include a relatively large proportion of harmless bacteria, which are normally inhabitants of falls and natural waters, free from dangerous pollution. The number of bacteria as estimated by the standard gelatine count serves in a general way as an index of the cleanliness of the sample; but to properly interpret the result of such a count it is necessary to have knowledge of the source of the sample examined and the nature of the pollution to which it has been exposed and the opportunity afforded for multiplica-

tion of the harmless varieties of bacteria present; on account of rapid multiplication of harmless varieties of bacteria which may take place when water is stored in small containers at moderate temperatures, and the impossibility of making approximately correct allowance for such multiplication, it is believed that the attempt to establish a limit to bacteria developing on gelatine is not practicable for the purposes of the control of supplies of common carriers.

"The bacteria developing on standard agar at 37° Centigrade in twenty-four hours are also chiefly varieties which are entirely harmless. The agar count, however, as compared with the gelatine count, represents a larger proportion of bacteria which find their normal habitat in the animal body and are present in sewage and other discharges from the animal body. Generally speaking, an accepted agar count is sufficient to cause at least a suspicion that the water is polluted with discharges from animal bodies, and is therefore unsafe for use as a drinking water. Multiplication of the harmless varieties present may, however, take place at ordinary temperatures in water stored in tanks, coolers, bottles, and other containers, thus greatly increasing the agar count without, of course, increasing the actual dangerous pollution of the water. This introduces a large source of error into the attempt to interpret the significance of agar count of samples of water stored for varying lengths of time under conditions more or less favorable to bacteria multiplication. It is largely for this reason that it has been considered necessary to allow varying limits to the agar count of the water supplies of common carriers, and to attach to the result of this method of examination a significance much less than ordinarily attaches to the agar count in examining samples of water especially removed from known sources.

"Bacteria of the bacillus coli group are normally inhabitants of the intestinal tract of warm-blooded animals, and it is believed that under ordinary conditions they do not multiply in nature outside of the animal

body; that in drinking water supplies they tend, on the contrary, to die out rather rapidly. The presence of such bacteria in the water may accordingly be considered valid evidence that the water has been polluted with the intestinal discharges of some of the higher animals, and the numbers present should be considered a fair index of the extent of such pollution. Since practically all of the diseases which are known to be commonly transmitted through water supplies are due to germs which are discharged from the intestines of infected persons, pollution with intestinal discharges is not only the most offensive but by far the most dangerous kind of pollution to which water supplies are exposed.

"Compliance with the requirements herein recommended will insure a quality of water supply equal to that of municipal supplies which have been demonstrated by experience to be entirely safe and satisfactory, and will at the same time impose no great burden upon common carriers, since it is entirely practicable with moderate direct expense and pains to purify water to the degree required."

A comment which may be made upon this report of the Treasury Commission is that, while the standard they set is proper under the conditions for which they place it,—that is, a single standard for the testing of large varieties of water from different unknown sources,—and will give practically a safe water under any such conditions, a somewhat more liberal standard might well be applied in the case of a municipal water supply where the source of the water is known and its possibilities of being subjected to pollution can be investigated on the ground. Under these latter conditions a higher *B. coli* content may be well in accord with a good and wholesome water.

INTERFERENCE WITH THE PRESUMPTIVE COLI TEST BY OTHER SPECIES OF BACTERIA.

For some time it has been known by bacteriologists that *B. Welchii, B. enteritidis,* and some other streptococci interfere with the so-called presumptive bile test for *B. coli.* The details of the discussion concerning these complications are beyond the scope,

bacteriologically, of this address. It is sufficient to state that they are serious and that they require far more consideration than was thought to be the case a few years ago.

It appears that *B. Welchii* and some other forms of bacteria grow anaërobically and ferment nutrient carbohydrate solutions, although they may not grow on aërobic plates.

Columbus Experiences.—One of the most striking experiences which have come to the attention of the speaker was noted a week or two ago in connection with the operating of the filtering and softening plant of the water works of Columbus, Ohio. This plant, skilfully operated under the charge of Mr. Charles P. Hoover, deals with very hard water during the autumn months. Lime and soda are added to soften it, and as a result large quantities of gelatinous, flocculent precipitate of basic carbonate of magnesia are formed. This brings about a very high degree of bacterial removal as an incident to the softening process and prior to filtration. In a single week there were five days on which numerous samples of the softened and filtered water showed in no instance any bacteria either on gelatine plates or agar plates cultivated either for forty-eight hours at 20° or twenty-four hours at 37°. By ordinary procedures the filtered water was sterile. Yet in fully half the samples of this sterile water positive results were found by the presumptive test for *B. coli* when 10 cubic centimetres of water were employed.

During the past autumn similar results, but less strikingly frequent, have been noted in connection with the operation of the softening and filtration plant of the water works at Grand Rapids, Mich., and the filtration plant at Evanston, Ill.

At Columbus the bacterial flora of the Scioto River water have been studied with unusual care by Messrs. Copeland and Hoover, who in the *Journal of Infectious Diseases,* vol. 8, p. 241, 1911, contributed an important paper on "The Interpretation of Tests for B. Coli Communis."

The concluding paragraph of this paper is of much practical importance to water works officials having the responsibility of caring for the quality of municipal water supplies:

> "*B. coli* is found in sewage, and therefore its presence is significant; but, as newspaper reporters and other persons are inclined to magnify conditions, the

officers in charge of purification works should be careful to identify suspicious organisms as true *B. coli* before throwing suspicion upon their plants and prejudicing the minds of the people. With this end in view, the procedure outlined in the diagnostic table gives a ready method of proving whether waters do or do not contain *B. coli communis,* and the necessity of such procedure is illustrated by the variety of organisms which less thorough tests would include erroneously in the group."

GOVERNMENT EXAMINATION OF DRINKING WATER ON RAILROAD TRAINS.

In Bulletin No. 100 of the Hygienic Laboratory of the United States Public Health Service, Treasury Department, there is an important paper on this subject by Richard H. Creel. This entire paper, appearing in November, 1914, is worthy of most careful study, and particularly with reference to the light it throws upon the "bile presumptive test for colon bacillus." It deals particularly with anaërobic bacilli, found in the water of train coolers, which complicate the ordinary so-called coli tests. It speaks of several groups of bacteria which are obligate anaërobes. Concerning the reliability of the presumptive tests, we quote as follows:

"Bile Presumptive Test for B. Coli."

"The difference between the actual *B. coli* percentage in the 1000 samples examined and that which would have resulted had the lactose bile presumptive test been used is as follows, the comparison applying only to tubes containing water in 10 cubic centimetre amounts:

Number of Samples	Gas	B. Coli	Anaërobe	Actual B. Coli Per cent.	Bile Presumptive B. Coli Per cent.
1,000	421	91	330	9.1	22.1

The margin of error is greater in relatively pure water than in water of moderate pollution.

"Estimated according to the different trains, the comparison is as follows:

	Actual *B. Coli* Per cent. Confirmed.	Percentage of *B. Coli* According to Lactose Bile Presumptive Test.	Number of Samples.
Train 301, Pennsylvania Railroad (sleeping cars)	4.7	25	151
Train 84, Seaboard	6.3	17.5	59
Train 305, Pennsylvania Railroad (sleeping cars)	3.4	20	125
Train 305, Pennsylvania Railroad (coaches)	5.3	16	57
Train 82, Atlantic Coast Line (coaches)	32.	54	50
Train 82, Atlantic Coast Line(sleeping cars)	14.	17	144

"It will be noted that there is a wide divergence between the real and the presumptive percentage when the water is fairly pure, but that in moderately polluted water, as that from Train 82, there is less discrepancy. In the latter class of water the approximation of the two figures seems to be due to the inhibiting effect of lactose bile on the *B. coli.* From the foregoing results the 'presumptive test' for *B. coli* does not seem applicable for analyzing water of moderate pollution, as its employment would often result in condemning a water of acceptable standard of purity."

RECENT ENGLISH COMMITTEE REPORT ON THE STANDARDIZATION OF BACTERIOSCOPIC METHODS OF WATER EXAMINATION.

In the autumn of 1914 a committee of thirteen leading bacteriologists and sanitarians appointed in March, 1914, by the Royal Institute of Public Health of Great Britain, reported on this subject. It is not practicable to repeat all of the technical details, but it is of interest to note what they say with regard to standards, especially in connection with the caution which they urge against wording reports to give unnecessary alarm, as follows:

"*Standards.*

"The committee do not think it is practicable to lay down any fixed standards to govern all cases. Speaking generally, the committee consider that too

much stress should not be laid on the number of microbes present in a water, unless the *B. coli* tests yield confirmatory results.

"A good water should not contain any *B. coli* in 100 cubic centimetres, but a water containing *B. coli* in 100 cubic centimetres should not necessarily be objected to without the examination of further samples.

"Experience has shown that even initially impure waters may be purified at a reasonable cost, so as to yield no *B. coli* in 100 cubic centimetres in the majority (about seventy-five per cent.) of samples examined.

"It is much more difficult to suggest a standard by which a water should be condemned. All that the committee feel justified in stating is that the further a water departs from the above standard of purity (no 'lactose + indol + ' *B. coli* in 100 cubic centimetres) the greater is the suspicion attaching to it, unless the local conditions and circumstances are such as to exclude undesirable pollution."

NEED OF FURTHER CONSIDERATION OF BACTERIOLOGICAL METHODS.

There is a feeling among some water works men that the recent standard proposed by the Federal Government for the quality of drinking water supplied to the public by common carriers in interstate commerce will cause annoyance and perhaps some serious trouble to municipal water supplies that are generally believed to be of safe and satisfactory quality. At any rate, the Treasury Department report above quoted from at length will unquestionably stir up a helpful agitation as to the reliability of bacteriological methods of analysis and accentuate the need of more care being exercised in the future than in the past.

No doubt there are places where the bile presumptive test for *B. coli* is markedly helpful, and its use in many places will no doubt be urged by the extremists who wish to be ultra-conservative in insisting upon the highest purity for public drinking water supplies. Nevertheless, the evidence, on the whole, points to the ease with which gross injustice against some important water supplies might be brought about.

It seems important to have the standard methods of bacterial water analysis thoroughly reviewed and brought to date. And it is understood that the American Public Health Association, through its Laboratory Section, appointed a new committee to deal with this subject (Jacksonville, Fla., Convention, December, 1914).

WATER SUPPLIES AND TYPHOID FEVER.

The general relation between deaths from typhoid fever in a community and the quality of the water supplied to it has long since been established. It is well known that ordinarily in towns where water supplies are relatively good, typhoid fever cases and deaths are relatively low, and for towns where a water supply is assumed to be impure the converse is true. The relation is, of course, not at all an exact one.

Table V gives the annual typhoid fever death-rate for various American cities, noted in deaths for 100,000 population, from the years 1880 to 1914. Notes are made of various improvements in the water supplies at certain times, and the change of death-rate accompanying this gives some information as to the resulting effect on the population.

In the first column are data for the city of Chicago, when at the beginning of the year 1894 or the end of the year 1893 a new intake was put into service. This is marked with a little note "4." The effect on the typhoid fever death-rate was very marked, indeed, as this rate dropped from 54 in 1893 to 38 in 1894, and it is probably safe to say that at least some part of this reduction is the result of the improvement of the water. In 1900 the new Chicago Drainage Canal was put into service. The effect of this introduction was, however, less marked.

The cities of Milwaukee and Detroit show a relatively uniform rate during the last twenty years, and no material change in the water supply system has been made in those cities during that time.

The city of Cleveland shows marked improvement, due to the introduction of a new intake in 1905, and again in 1912, when the water was sterilized for the first time.

In the column showing the deaths in the city of Buffalo there are no very significant figures. A new intake was introduced

in 1911, but the time since then is rather too short to suggest any positive inferences.

For the city of Toronto the filtration plant was started in 1911.

TABLE V.

ANNUAL TYPHOID FEVER DEATH-RATES FOR VARIOUS AMERICAN CITIES IN DEATHS PER 100,000 POPULATION

Year	Chicago	Milwaukee	Detroit	Cleveland	Buffalo	Toronto	Boston	New York	Manhattan and the Bronx	Philadelphia	Baltimore	Washington	Cincinnati	Pittsburgh	San Francisco	St. Louis	New Orleans
1880	34	37	..	44	..	44	42	25	..	58	59	54	70	135	34	40	24
1881	105	47	..	99	67	66	56	38	..	74	58	46	71	151	37	53	30
1882	82	32	..	68	69	71	57	32	..	73	47	66	55	158	61	45	33
1883	62	25	..	65	34	81	52	32	..	64	35	62	51	107	64	41	23
1884	56	31	..	60	42	63	56	29	..	71	42	76	56	70	58	42	25
1885	75	28	..	34	23	59	40	27	..	64	42	65	42	76	44	31	17
1886	69	30	39	56	28	46	34	26	..	64	39	71	54	68	49	30	13
1887	50	31	65	52	34	61	44	26	..	63	41	78	142	128	23	28	15
1888	47	42	46	47	29	52	40	23	..	77	42	87	70	87	33	31	19
1889	48	28	31	74	30	46	43	24	..	71	47	94	49	95	55	33	17
1890	92	41	19	69	40	93	35	22	..	64	59	112	69	132	44	31	21
1891	174	33	34	50	51	100	34	23	..	64	35	82	62	101	42	29	24
1892	124	30	94	59	34	47	29	22	..	40	44	89	40	100	32	93	20
1893	54[4]	35	42	52	37	45	31	21	..	41	49	86	44	111	32	44	15
1894	38	25	28	29	59	26	29	17	..	33	47	91	55	56	37	34	29
1895	38	26	24	35	26	27	33	17	..	40	36	86	39	78	34	21	44
1896	53	18	23	43	20	27	31	16	..	34	38	58	52	62	26	20	33
1897	29	12	15	23	20	18	33	16	..	33	37	48	32	64	19	23	52
1898	41	17	22	34	27	16	34	21	..	52	36	71	33	73	41	17	66
1899	27	17	13	32	24	20	30	16	..	75	29	73	37	111	22	23	55
1900	20[3]	17	27	54	26	20	26	21	..	35	35	78	39	144	13	29	40
1901	29	22	21	36	27	17	25	20	..	34	27	60	55	125	22	34	48
1902	45	15	24	33	33	13	24	21	..	44	42	78	62	134	27	37	45
1903	32	17	20	114	35	16	20	17	..	69	36	48	42	134	..	47	39
1904	20[4]	14	20	48	23	23	23	17	..	53	37	47	79	142	27	36	36
1905	17	23	21	15[4]	23	16	20	16	..	48	36	48	40	99	24	20[5]	32
1906	19	31	24	20	23	26	20	15	..	72	35	50[1]	70	130	..	17	30
1907	18	26	35	19	28	22	10	17	..	59	41	35	45	125	..	15	55
1908	16	17	22	13	20	20	25	12	11	35	33	37	18[1]	45	..	14	33
1909	13	23	23	13	23	23	14	12	12	21[1a2]	25	33	13	23[1]	..	16	29[1]
1910	14	45	20	19	20	41	12	12	11	17	42	23	6	28[2]	..	13	32
1911	11	19	17	15	25[4]	20[1]	9	11	10	14	27	21	11	26	..	11	31
1912	8	25	18	6[2]	11	12	8	10	7	13	24	22	7	13	14	14	14
1913	11	11	29	13	15	10	8	7	6	16	26	..	6	19	..	16	17
1914	7	8	12	8	16	7	9	6	5	7	22	..	6	..	..	11	20

Note: New York includes Borough of Manhattan only through 1898—since 1898 Greater New York

[1] Filtration effective for city.
[2] Sterilization of water supply begun.
[3] Drainage Canal in service.
[4] New intake
[5] Coagulation introduced.

The city of Boston shows a rather satisfactory and gradual reduction of typhoid during the last twenty years, without any very marked changes in the entire water supply. In 1898 the Wachusetts water supply was introduced, showing some reduction in typhoid fever as a result.

For the city of New York the reduction has also been rather gradual. The only notable point is for the year 1893–1894,

when particular measures were taken to reduce the pollution on the Croton watershed by removing sewage discharges from houses within a 300-foot line of the reservoirs and principal feeders.

The situation in the city of Philadelphia you are no doubt all familiar with. The filters, which have improved the typhoid situation to such a marked extent in this city, were introduced gradually, beginning about the year 1903. The West Philadelphia Belmont filters were added in 1906; the Torresdale plant was started in part service in 1907. By the year 1909 most of the city was supplied with filtered water, and where no filtered water was afforded the balance was sterilized. The final addition of the Queen Lane plant, in 1911, gave filtered water to the whole city. The reduction in typhoid fever as a result of this gradual introduction of filtered water into the city is very noticeable. In 1914 Chief Davis states that the annual death-rate from typhoid fever was 7.48 per 100,000.

The city of Baltimore shows no very marked reduction, but, with the addition of the new water filters which will be in operation before very long, we can expect to find quite a lessening of the typhoid rate.

The city of Washington showed rather disappointing results in the matter of filtration, particularly in the earlier years. Although the reduction of typhoid at first was by no means as marked as was expected in advance, yet the later figures have been much more satisfactory.

The figures for the city of Cincinnati following filtration are quite remarkable. The reduction was very sharp, and the typhoid rate for the last five or six years has been only about one-third, or even less, of what it was during the preceding years.

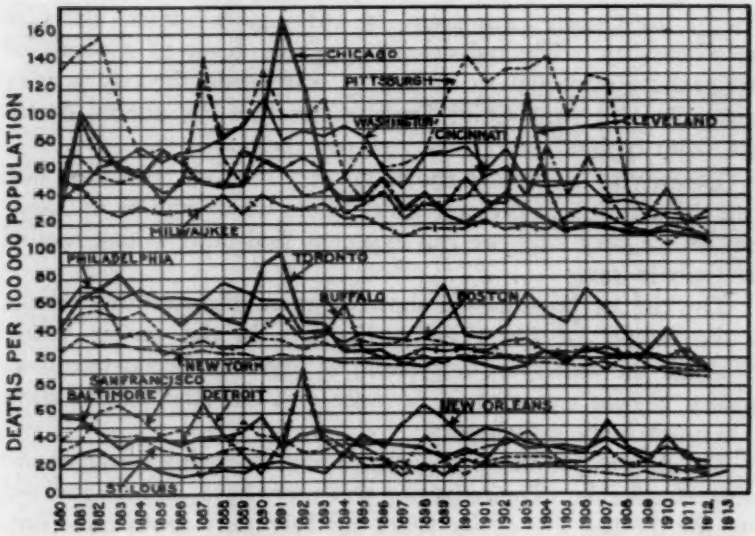
The city of Pittsburgh shows similarly satisfactory results. The introduction of filtered water in 1909 effected a very marked reduction of typhoid fever, even if some unfiltered water was still supplied.

In the column showing the results in the city of St. Louis a moderately satisfactory reduction has been effected by the addition in the year 1904 of the coagulating plant to the St. Louis water works system, aided by prolonged sedimentation arrangements and later by sterilization. Filters are now being built.

The New Orleans results show some satisfactory reduction recently, but a good deal less than has been found in other cities.

Fig. 1 shows the results of the foregoing table represented graphically. The scale of the drawing does not indicate very clearly what the effect of changes in the water supply has been. A few of these curves stand out very clearly. In the upper line the reduction in the typhoid rate of the city of Pittsburgh is remarkable over all the others. The line showing the city of Cincinnati gives a very marked reduction. In the second line the effect on the city of Philadelphia is very noticeable.

FIG. 1.



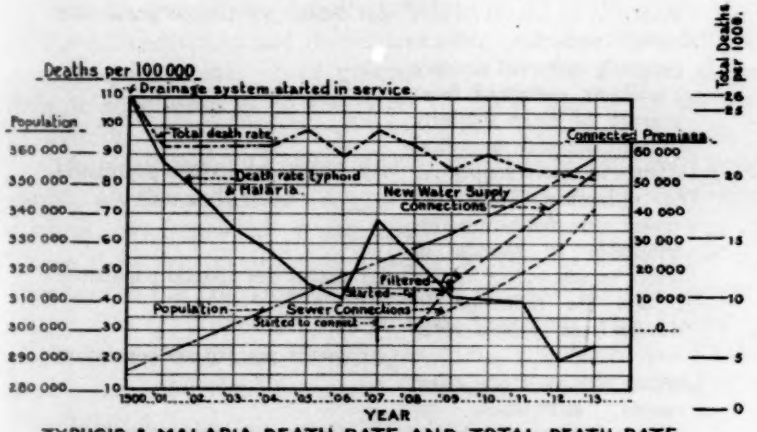
ANNUAL TYPHOID FEVER DEATH RATES FOR VARIOUS AMERICAN CITIES

Fig. 2 shows some detailed results from the city of New Orleans. Here are plotted the deaths for each year per 100,000 population from typhoid and malaria combined. These figures are, of course, materially higher than the typhoid deaths alone, but it seems not unlikely that they represent more accurately the improvement effected by the introduction of the sanitary sewer system and the new filtered water supply. A part of the surface drainage system was put in service in 1900. Sewer connections to the sanitary sewer system were started

in the year 1907 and have gradually increased. The filtered water supply was started by the city in the year 1909.

From the start of the surface drainage system a very satisfactory reduction in typhoid fever and malaria is to be found. During 1913 the deaths from typhoid were seventeen per 100,000, and for malaria six, making a total of twenty-three per 100,000 population, a figure not at all unsatisfactory, when it is considered that there is still a part of the city not supplied with either sewer connections or filtered water, and that local conditions of temperature, flies, and other items, exercise a material effect on the

FIG. 2



TYPHOID & MALARIA DEATH RATE AND TOTAL DEATH RATE & SEWERAGE & WATER SUPPLY & DRAINAGE. NEW ORLEANS - LA.

typhoid and malarial fever death-rate. The removal of storm water and sewage which formerly pooled on the surface of the ground has been the controlling item.

HAZEN'S THEOREM.

In the year 1893 it was stated by Dr. J. J. Reinicke, of Hamburg, Germany, and Mr. Hiram F. Mills, C.E., of Lawrence, Mass., that the purification of the polluted public water supplies of Lawrence and Hamburg was producing a general decline in the death-rate of each of these cities. In 1904 Mr. Allen Hazen, in his paper on "The Purification of Water for Domestic Use" before the International Engineering Congress, formulated a deduction from certain data similar to this, as follows:

"This computation indicates that where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided. This seems the clear and logical conclusion from the statistics."

Mr. Hazen's tabulation from which he deduces this statement is the following:

Reduction in total death-rate in five cities with the introduction of a pure water supply	440 deaths per 100,000 population
Normal reduction, due to generally improved sanitary conditions, computed from average of cities similarly situated, but with no radical change in water supply ...	137 deaths per 100,000 population
The difference being decrease in death-rate attributable to change in water supply	303 deaths per 100,000 population
Of this the reduction in deaths from typhoid fever was	71 deaths per 100,000 population
Leaving deaths from other causes attributable to change in water supply ...	232 deaths per 100,000 population

This question was further considered in detail by Professor W. T. Sedgwick and Mr. J. Scott McNutt, in the *Journal of Infectious Diseases*, vol. 7, p. 489, in their paper entitled "On the Mills-Reinicke Phenomenon and Hazen's Theorem Concerning the Decrease in Mortality from Diseases other than Typhoid Fever Following the Purification of Public Water Supplies."

The authors of this paper came to a conclusion as follows:

"Mr. Hazen's quantitative expression for the Mills-Reinicke phenomenon, when applied to the cities which we have studied (with the exception of Watertown), appears sound and conservative. It seems

likely, however, that it will be impossible in the future to confine the relation even within the broad numerical limits suggested by Mr. Hazen."

This general subject is dealt with by the speaker in his book on Sewage Disposal, pp. 107–16. It appears that the Hazen theorem seems to apply chiefly in those cities having formerly a grossly-polluted water supply. Where improved supplies have been installed for cities which previously had only a moderately-polluted supply the improvement in general death-rate has been far less marked than at Lawrence, Albany, Hamburg, etc.

The danger of too definite conclusions as to the exact effect of the filtered water and its relative effects on the typhoid death-rate is quite great. Still greater may be the danger of any definite conclusion as to the effect of water supply on the total or general death-rate.

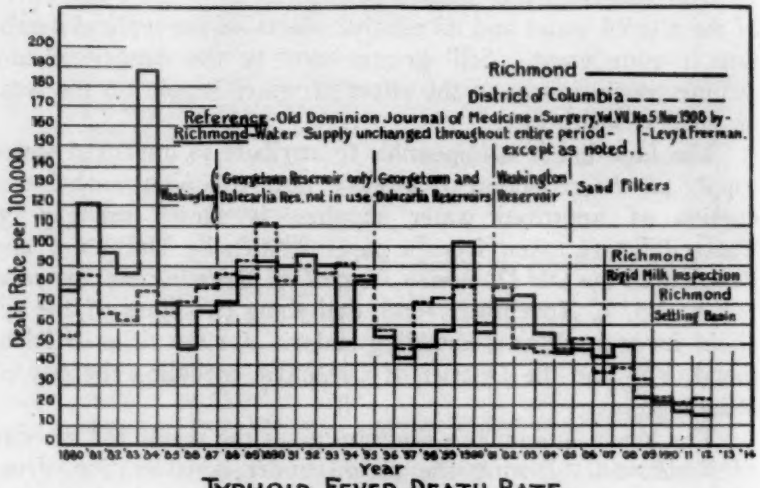
The fact that it is impossible to attribute to improved water supply all the reduction of typhoid rate, following such introduction of improved water supplies, is shown on Fig. 3. These data are taken from a paper written by Drs. Levy and Freeman in the *Old Dominion Journal of Medicine and Surgery*, vol. 7, No. 5, November, 1908, and show two lines of the typhoid fever death-rate, including malaria, for the cities of Richmond, Va., and the District of Columbia, including the city of Washington.

The heavy line on this diagram gives the result for the city of Richmond. During the period under consideration, from 1880 to 1909, there was practically no change made in the city of Richmond water supply. The Richmond water is not filtered, but there is no reason to believe that there was any great amount of pollution or disease resulting from this unfiltered water. In the year 1909 an additional settling basin was provided for the Richmond water supply, as noted on the digaram.

The Washington water supply, as shown in the diagram, was considerably improved during this period. At the end of 1887 we note that only the Georgetown Reservoir was in use. In 1895 the Dalecarlia Reservoir was added. In 1901 the Washington Reservoir was added. The filters were put into service in 1905.

Broadly speaking, there seems to be no particular difference between the typhoid fever rate shown in the Washington and the Richmond cases. There are some specific cases where very high figures are shown in Richmond, notably in 1880 and 1881, when there seems to have been an epidemic. In 1884 there was a very heavy epidemic indeed. In the year 1900 the Richmond curve shows likewise an epidemic. Apart from these special dates, the Richmond curve practically follows the Washington curve, and the typhoid fever rate is almost the same throughout. It is particularly noticeable in the later years since the Washington filters were added. Since this time a marked improvement in

FIG. 3.


Richmond
District of Columbia
Reference - Old Dominion Journal of Medicine & Surgery, Vol. VII, No. 5, Nov. 1908 by - Levy & Freeman.
Richmond - Water Supply unchanged throughout entire period - except as noted.
Georgetown Reservoir only
Georgetown and Dalecarlia Reservoirs
Washington Reservoir
Sand Filters
Richmond
Rigid Milk Inspection
Richmond
Settling Basin
Death Rate per 100,000
Year

TYPHOID FEVER DEATH RATE
(Including Typho-Malaria)
RICHMOND & DISTRICT OF COLUMBIA
1880–1914

typhoid fever has been found at Washington, and a similar improvement can be found in the city of Richmond. The improvement in the city of Richmond was largely caused by sanitary measures, particularly that of instituting a rigid milk inspection. The date of the starting of this rigid milk inspection is noted on the diagram.

It is not an unfair inference to say that a large part of the reduction in typhoid fever in Washington was owing, not to this improved water filtration, but to other sanitary measures which were introduced at about the same time.

There is one important factor, however, which differentiates the effect of an unfiltered water supply from the effects of a filtered water supply. An unfiltered water supply which may be subjected to occasional gross pollution may produce at intervals a very serious epidemic. Such an epidemic may easily run the typhoid fever rate to several times the normal for a period of a year. Such an epidemic can hardly occur with a properly-filtered water supply. In this lies the particular value of filtration. Typhoid fever as a whole may or may not be reduced in any particular locality by the introduction of filters. In some cases there has been a marked reduction of typhoid attributable only to the filtration and to nothing else. In other cases, as at Washington, such reduction as has been noted is probably not to be attributed chiefly to the filters, but to other sanitary measures.

It is not to be asserted as a general rule that filters must eliminate the typhoid fever and other similar sicknesses in any town. It can, however, be asserted without qualification that such filters will practically eliminate any chance of a typhoid epidemic, and thus make the water supply safe. A surface water supply without filtration or sterilization or prolonged storage cannot ordinarily and uniformly be considered safe. Even under the best of conditions and under the most favorable inspection the water of flowing streams may at times be subjected to pollution which may cause typhoid epidemic.

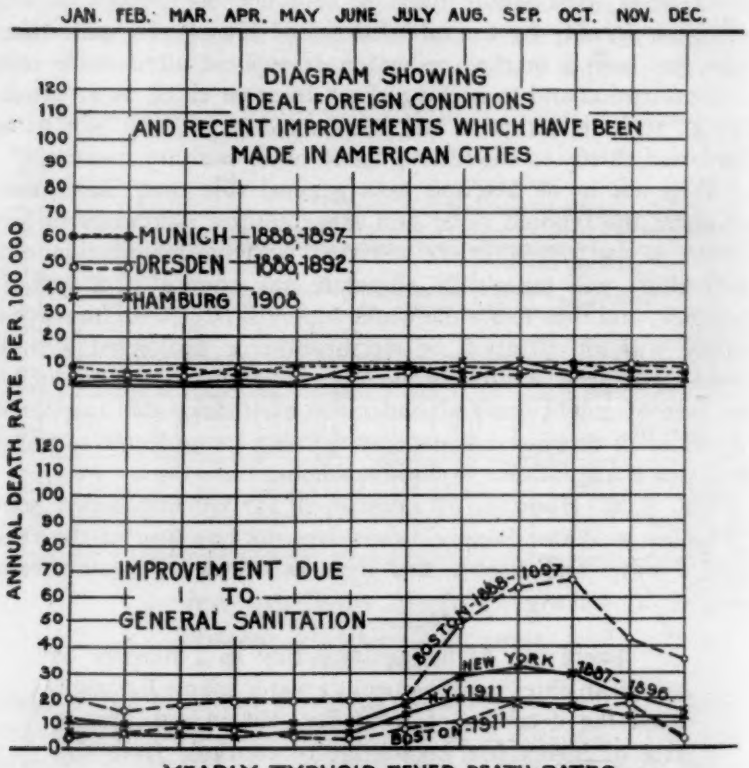
Dr. A. C. Houston, of London, in his recently-issued book "Studies in Water Supply," considers the question of the relation of water and disease, and from this book we quote several sections, as follows:

> "There can be no question that in a number of American cities improvement of water supply has antedated the decrease of mortality, but in our present state of incomplete knowledge to conclude from this circumstance a direct causative connection between these two is perhaps hardly warrantable in all cases.
>
> "The fact that there has likewise occurred a decline in the incidence of tuberculosis, pneumonia, and respiratory diseases generally, none of which can reasonably be regarded as at all likely to be water-borne, throws some doubt on the hypothesis that an improved

water supply necessarily tends to produce any marked and continuously operating decrease of mortality from general and particular diseases.

"The author is, of course, not suggesting, in the face of conclusive evidence to the contrary, that serious typhoid epidemics have not resulted from the consumption of specifically polluted water, or that any relaxation in the processes of water purification is permissible; he does venture to express the opinion that the evidence brought forward in favor of the direct causative relationship between the quality of water supplies and the degree of incidence of endemic typhoid fever is not always wholly convincing.

FIG. 4.

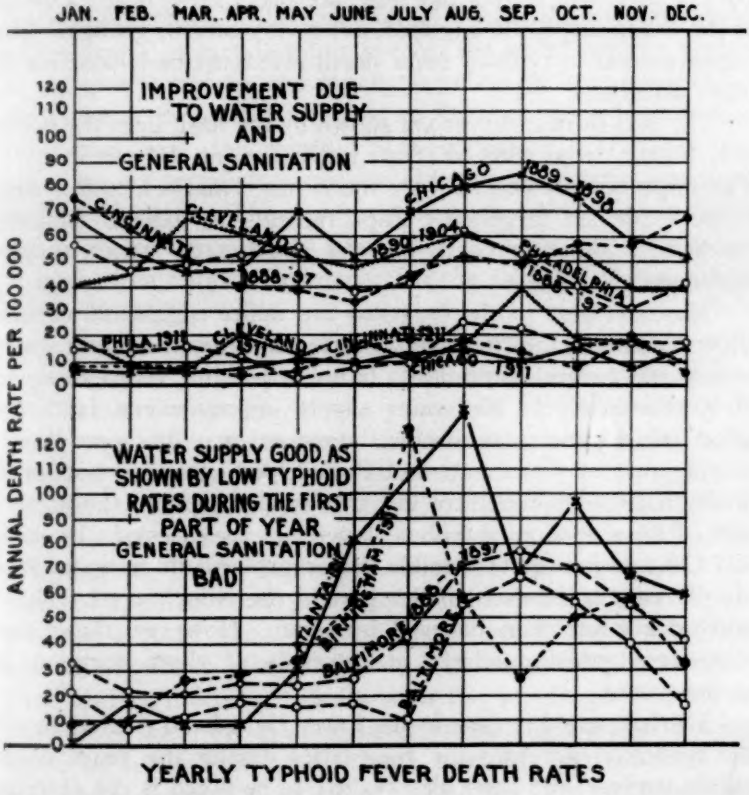


YEARLY TYPHOID FEVER DEATH RATES.

> "It is impossible, of course, to accept any theory which associates diminution of the typhoid fever rate as attributable to improved water supply, but seems to ignore increased incidence of the disease as of water significance."

Fig. 4, modelled after Jackson's data in his Cleveland report of 1913, shows some yearly typhoid fever death-rates

FIG. 4.—(*Concl.*)


JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEP. OCT. NOV. DEC.
IMPROVEMENT DUE TO WATER SUPPLY AND GENERAL SANITATION
CHICAGO 1889-1890
CLEVELAND 1890-1904
CINCINNATI 1888-97
PHILADELPHIA 1888-97
PHILA 1911
CLEVELAND 1911
CINCINNATI 1911
CHICAGO 1911
WATER SUPPLY GOOD AS SHOWN BY LOW TYPHOID RATES DURING THE FIRST PART OF YEAR
GENERAL SANITATION BAD
CINCINNATI 1911
CHICAGO 1889-1897
BALTIMORE 1889-1897
BALTIMORE 1911
ANNUAL DEATH RATE PER 100 000
YEARLY TYPHOID FEVER DEATH RATES

under various conditions for a number of cities. The first section, in the upper left-hand corner, gives a diagram showing certain foreign cities (Munich, Dresden, and Hamburg) with actual annual typhoid fever death-rates per 100,000, running in all cases below ten and averaging about five. The conditions represented by these figures are practically ideal. It is well

worthy of note in these lines showing death-rate for various months during the year that incidence of typhoid fever is practically constant during the whole year.

The second section of the diagram, in the lower left-hand corner, shows improvements effected in two cities by general sanitation. The heavy line represents the city of New York. The upper line shows the New York typhoid for the years 1887–1896; the lower solid line, New York conditions for the year 1911. There has, during this time, been very little, if any, change in the water supply; in any case, not a very serious change. The improvements in typhoid fever death-rate must be looked for in other directions.

The two Boston curves are shown by the dash line: the upper one, Boston from 1888 to 1897; the lower one, Boston in 1911. The improvement here is very much more marked, and is also to be explained largely by improvements in general sanitary conditions, although partly by the Wachusetts water supply, introduced in 1898.

The next part of the diagram, the upper right-hand corner, shows combined improvements effected through change in water supply and general sanitation. It is not possible very exactly to divide the effect of the water supply improvements from the effect of a general sanitation improvement. In some cases, notably that of Cincinnati and Philadelphia, there is not much doubt that the improvement in water supply explains the greater part of the reduction of typhoid fever. In the cases of Cleveland and Chicago it is quite possible that improvements in water supply played a somewhat smaller part in the reduction of typhoid fever death-rate than believed by some. However, these supplies were grossly polluted at intervals of short duration in earlier years.

The last set of curves, in the lower right-hand corner, shows the typhoid fever rate for four cities during the years noted on the curve. The particular feature to be noted is the extreme range of typhoid fever during the various parts of the year—low during the months of January and February, and very high during the summer months. The inference to be drawn is that the water supply, which does not change noticeably during the year, is to blame for only a relatively small part of the typhoid, and that the greater part is to be explained by other causes, such

as the milk supplies, mosquitoes, flies, and other disease-spreading insects which thrive during the warmer months. It is worthy of note that the cities of this diagram come from the southern latitudes, where the effect of climate is more marked, especially as to the duration of the fly period.

SEASONAL DISTRIBUTION OF TYPHOID FEVER.

It has been noted for many years that typhoid fever shows a marked difference in the cases found during the various seasons of the year. At certain times, notably the colder months, typhoid in some cities may be, and usually is, relatively low; while during the summer months, from July to October, very high typhoid fever rates are often noted. Such variations of typhoid fever incidence do not always, if ever, correspond to variations in the quality of water. The water supply may indeed vary in quality and be materially worse at some seasons of the year than others. It may often happen, however, that the times of bad quality of the water supply follow the times of high incidence of typhoid fever by an appreciable period. This may be taken to show rather definitely that the initial cause of the high typhoid fever rate at certain seasons of the year does not depend upon the water supply, but more likely the bad water supply may be the result of earlier typhoid fever conditions.

Fig. 5 shows in a little more detail the seasonal distribution of typhoid fever for the cities of Birmingham, Ala.; Washington, D. C.; Richmond, Va., and Baltimore, Md. The rates of typhoid fever indicated for the months from January to June average about twenty deaths per 100,000 population, and this figure is fairly uniform. Starting with the month of June and culminating usually with the month of August, but sometimes later, the typhoid fever deaths rapidly rise to a high figure of somewhere from seventy to eighty per 100,000. The real cause of such typhoid fever death-rates is to be found in the prevalence of flies under unfavorable sanitary conditions, such as unscreened privies and other unprotected sources of possible pollution, the prevalence of mosquitoes during the summer months, the possibility of bad milk during this season, and other similar sources of infection.

Fig. 6 illustrates the seasonal distribution of typhoid fever in the city of Jacksonville, Fla. The three curves given are for the three years, 1910, 1911, and 1912, 1910 being the solid line showing the highest rate, 1911 the dashed line showing the intermediate rate, and 1912 the dot-and-dash line showing the lowest rate. As in the previous diagram, the typhoid fever death-rate in the winter months was relatively low, around twenty

FIG. 5.

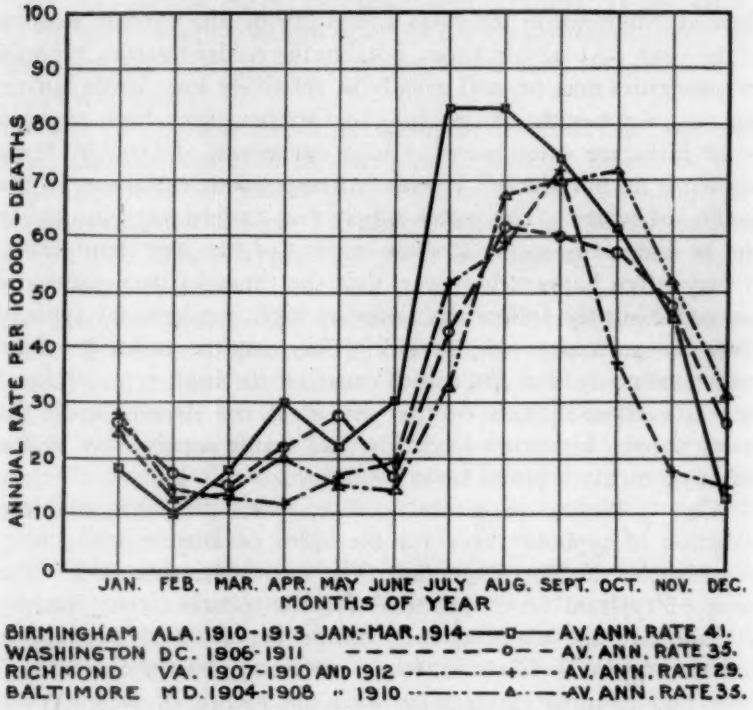

ANNUAL RATE PER 100000 - DEATHS
100
90
80
70
60
50
40
30
20
10
0
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
MONTHS OF YEAR
BIRMINGHAM ALA. 1910-1913 JAN-MAR. 1914 —□— AV. ANN. RATE 41.
WASHINGTON D.C. 1906-1911 - - - - - - - -o- - AV. ANN. RATE 35.
RICHMOND VA. 1907-1910 AND 1912 -·—·—·—+—·—· AV. ANN. RATE 29.
BALTIMORE MD. 1904-1908 " 1910 ···——···—△···— AV. ANN. RATE 35.

DIAGRAM SHOWING SEASONAL DISTRIBUTION OF TYPHOID FEVER

per 100,000. During the warm summer months the typhoid fever cases and rates were very high. On the same reasoning as before noted, it is to be expected that these high summer rates were attributable to flies or other similar causes.

In this actual case, that of Jacksonville, it may be said that the proof of the pudding was in the eating, for the improvement shown by the three curves was effected on the theory above noted.

The heavy line shows the 1910 typhoid fever case rate, when all privies and water-closets were left in their ordinary loose, unscreened, and unprotected condition. In this year the rate ran up to 110 in the month of July. After this a start was made in cleaning up and making fly- and mosquito-proof all these

FIG. 6.

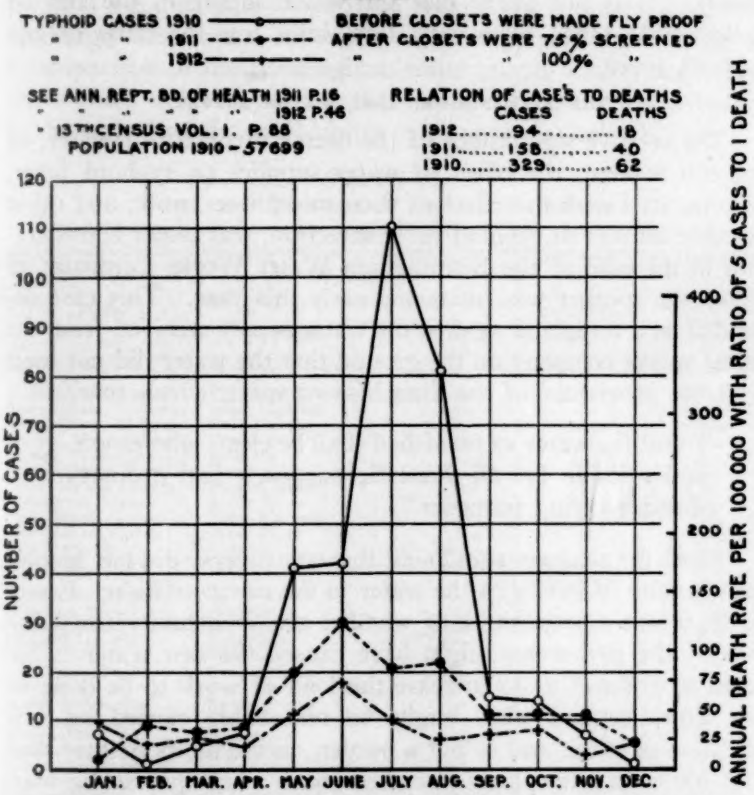


DIAGRAM SHOWING SEASONAL DISTRIBUTION OF TYPHOID FEVER JACKSONVILLE — FLA.

water-closets and privies. The curve in 1911 shows the results of this work. The highest rate reported for the year 1911 was thirty in the month of June. During this summer, 1911, seventy-five per cent. of the closets were screened. In the year 1912 all the closets were screened and the highest rate recorded was eighteen in the month of June.

Taking the whole year, we find that the typhoid cases were, for the years 1910, 1911, and 1912, 329, 158, and 94, respectively, and that the deaths for these years were 62, 40, and 18, respectively.

There exists very little doubt that all the improvements which have been made were the result only of the cleaning of the closets. It is not likely that the water supply in the city of Jacksonville, taken from very deep wells, was the cause of any typhoid fever.

THE BIRMINGHAM, ALA., WATER SUPPLY.

The relative significance of the bacterial content of water, of the coli content, the effect of water supplies on typhoid fever, as compared with the effect of flies, mosquitoes, milk, and other possible sources of typhoid fever infection, was under consideration in the case of the Birmingham Water Works Company, in which the speaker was interested early this year. This case depended on a complaint against the water supply received from the water works company on the ground that the water did not meet with the provisions of the franchise compact, which specified

> " that the water so furnished shall be clear, wholesome, and suitable for all domestic purposes, and ordinary manufacturing purposes."

From the sanitary standpoint this controversy did not involve the question of purity of the water in the raw condition. Essentially, it was a proposition of whether the opportunity for pollution of the raw water might have caused the raw water to become so polluted as to increase the load of work to be done by the filters beyond what might be reasonably caused by safe filtration practice, and so put a burden on the filters greater than that found in filter plants elsewhere, such as are producing what might be fairly termed pure and wholesome water, as that expression is used in the practical art of water supply and water purification.

The first step in the investigation of this problem was a visit to the watershed and an examination of local conditions. On going over the watershed of Five Mile Creek no seriously objectionable conditions were found. There were occasionally a few farmhouses. No villages existed on the watershed, and

there was no sign of any direct sewage pollution. There remained, of course, the opportunity for indirect contamination, owing to soil wash, and the possibilities of the flushing of polluted matters by heavy rains into the feeders of the various streams above the head of the canal.

Considering the total population tributary to the water supply, and a comparison to see if an unduly large number of people discharge their waste into this water supply, Table VI shows a comparison of the Birmingham water supply with a number of other cities to show what is the density of population tributary to the watershed from which the city supply is derived.

TABLE VI.

POPULATION RESIDENT ON CERTAIN WATERSHEDS.

Note—Populations per square mile, except Birmingham, refer to 1900 population.

Name	Waterahed		Population	Supply filtered
	Name	Area square mile		
Birmingham, Alabama	Five Mile Creek	16.2	35	Yes
Birmingham, Alabama	Main Cahaba	152	10	Yes
Birmingham, Alabama	East Cahaba	49	44	Yes
Boston, Massachusetts	Cochituate	18.7	775	No
Boston, Massachusetts	Sudbury	75.2	294	No
Boston, Massachusetts	Wachusetts	118.2	48	No
Lynn, Massachusetts	Saugus River	10.6	710	No
Springfield, Mass.	Little River	50.0	13	Yes
New Haven, Conn.	Lake Whitney	37.7	80	Yes
New Haven, Conn.	West River	13.6	50	No
New York, N. Y.	Croton	360.0	70	No
New York, N. Y.	Catskill	426.0	Winter 20 Summer 36	No No
Jersey City, N. J.	Rockaway	121.0	157	No
Paterson, N. J.	Passaic	773.0	22	Yes
Philadelphia, Pa.	Delaware	8186	30	Yes
Philadelphia, Pa.	Schuylkill	1915	98	Yes
Chester, Pa.	Delaware	10450	173	Yes
Harrisburg, Pa.	Susquehanna	24300	41	Yes
York, Pa.	Codorus	100	90	Yes
Wilkes-Barre, Pa.	Spring Brook	53	9	No
Wilkes-Barre, Pa.	Mill Creek	10	12	No
Wilkes-Barre, Pa.	Huntsville	15	27	Yes
Baltimore, Maryland	Jones Falls	39	154	No
Baltimore, Maryland	Gunpowder Creek	306	73	Building
Columbus, Ohio	Scioto	1050	70	Yes
Lawrence, Mass.	Merrimac	4634	69	Yes

It appears that the Five Mile Creek watershed contained a population of thirty-five to the square mile; the main Cahaba watershed a population of ten to the square mile; and the east Cahaba watershed a population of forty-four to the square mile. As compared with this, the old Boston watershed, Cochituate supply, has a population as high as 775 to the square mile; the Saugus River watershed, for Lynn, Mass., a population

of 710; the Rockaway watershed, supplying the city of Jersey City, a population of 157 per square mile; the Delaware River watershed, supplying the city of Chester, 173 per square mile; the Merrimac watershed, supplying the city of Lawrence, a population of 69 per square mile.

So far as this particular item of population goes, it can readily be seen that for this case, that of Birmingham, the population on the watershed is among the lowest of those recorded, and that no great danger of pollution is to be expected on the score of excessive population.

In addition to the question of the number of people residing on the watershed, there is always the possibility of accidental pollution. This potential danger particularly leads to the needs for filtration and sterilization of water supply. The likelihood of such pollution is best measured by the presence of the *B. coli* in the water.

The records of the occurrence of *B. coli* in one cubic centimetre of water are shown in Table IV. The records are given for the four years from 1910 to 1913. The raw water shows roughly eighty per cent. positive occurrence of *B. coli* in one cubic centimetre of water by the presumptive test. This water is filtered before being supplied to the consumers. As compared with other water under similar conditions, the water is much the same as that of the Passaic River supplying the Little Falls plant of the New Jersey Water Company. It is somewhat better than the water of the Hudson River reaching the Albany filters, and somewhat better than the water of Brandywine Creek in the Wilmington filters, and somewhat better than the water supplied to London for filtration.

After filtration there was from 0 to 9.7 per cent. of positive tests showing *B. coli* in one cubic centimetre. This, as compared with other waters, under similar conditions, shows very well. It is somewhat better than some of the waters, somewhat worse than others.

On the basis of typhoid fever death-rates, which are often taken as an indicator of the quality of the water supply, it is to be noted that the city of Birmingham, based on the 1910 population, showed in 1910 a death-rate of forty-eight per 100,000 population; in 1911, forty-seven; in 1912, forty-two; in 1913, forty-five. These rates are, of course, relatively high, but compared

with some twenty-nine southern cities of the larger size, having an aggregate population of something like two million people, the average of these twenty-nine cities showed an annual death-rate of fifty-seven per 100,000 population. In 1911, out of these twenty-nine southern cities, sixteen had a higher typhoid rate than Birmingham.

Birmingham conditions, as compared with other cities, have been illustrated in the data already shown. (See Fig. 5.) The explanation of the typhoid fever rate at Birmingham is not to be found in the water supply, but in the conditions of unprotected privies and other similar sources of pollution, whose infected contents are spread mostly by flies and mosquitoes.

A rather interesting feature of the water supply at Birmingham is the fact that the water from the Five Mile Creek watershed is sterilized after being filtered and shows no *B. coli* as delivered to the consumer. Water from the other watershed, the Cahaba, is not sterilized, but it is filtered, and shows an appreciable number of *B. coli*. Though the *B. coli* prevalence shown in one case is materially higher than in the other case, the typhoid fever of the two districts is roughly the same.

Certain parts of Birmingham are well sewered, but in these high-grade residential districts the prevalence of typhoid fever during the fly period was about as great as in the unsewered districts.

During the winter, or non-fly period of the year, the typhoid death-rate was low in all parts of the city.

It is logical to conclude that the occurrence of a moderately limited number of *B. coli* in any water means nothing as to the quality of the water, as opposed to a water which will show no *B. coli* whatever. It is only when the coli content becomes markedly high that it can be deduced that the water is, in consequence, unreasonably polluted.

As at Jacksonville, it was the fly and mosquito that transmitted typhoid at Birmingham.

The Density of Oxygen. A. F. O. GERMANN. (*Journal of Physical Chemistry*, vol. xix, No. 6.)—A brief historical survey of the more important determinations of oxygen is made, followed by a detailed account of the modern methods adopted in the Geneva Laboratory in the determination of gas densities, with particular reference to the purification of the gas used. An improvement in the globe method, as it has been developed in Geneva, is described, consisting of the simultaneous use of a number of barometers equal to the number of globes employed. The density of oxygen was revised, operating on gas furnished by the decomposition of potassium permanganate and purified by fractional distillation. Fifteen determinations led to the value of a "normal litre" under a pressure of 760 mm. of mercury at the temperature of melting ice at sea level in latitude 45° north: $L_n = 1.42906$. This value, taking into consideration the results of Morley and Rayleigh, leads to the value $L_n = 1.42905$, which represents, at the present time, the most probable value for the weight of the normal litre of oxygen.

The Purchase of Coal on a B. T. U. Basis. From "Coal for the Navy," J. O. RICHARDSON. (*Journal American Society of Naval Engineers*, vol. xvii, No. 2.)—The Navy Department has frequently been urged to purchase coal under strict specifications that provide that the purchase price shall be a certain figure for coal that shows a heating value of a certain number of British thermal units per pound; that coal which falls below or exceeds in calorific value this number shall be purchased at a price less or greater than the base price by an amount depending upon the number of B. T. U.'s below or above the standard. Theoretically this is an ideal way of purchasing coal, but practically it is very unsatisfactory, because it frequently happens that coal which in a laboratory test would be rated very high on a B. T. U. basis gives very poor results when burned in the furnace of marine boilers, and conversely.

In fact, one of the very best steaming coals in the market, and one which is largely used by sea-going steamers, would be barred from competition because of its lower B. T. U.'s than other first-class coals, and would therefore be forced to accept a lower price than such coals or abandon the navy trade, which it probably would. This coal, George's Creek, has long been recognized by marine engineers as one of the most satisfactory in the market. This method of purchasing coal would no doubt cause many disputes between the suppliers of coal and the Navy Department, and in the end would be unsatisfactory, because the navy is not buying so many heat units, but is buying high-grade coal that by actual use has been shown to be the best coal obtainable for naval boilers, and the suitability of the coal for the duty required should be the controlling factor in the purchase of coal for use on board naval vessels.

A RELATION CONCERNING THE DISTRIBUTION OF AN ELECTROLYTE BETWEEN WATER AND SOME SECOND SOLVENT AND ITS DISSOCIATION CONSTANT IN AQUEOUS SOLUTION.*

BY

HENRY JERMAIN MAUDE CREIGHTON,

Department of Chemistry, Swarthmore College.
Member of the Institute

INTRODUCTION.

ALTHOUGH the application of the laws of mass action to a very large series of reactions between ions and undissociated molecules has received excellent verification, and Ostwald's dilution law has been proved to hold for a large number of binary electrolytes, investigation has shown that it apparently fails in the case of the so-called strong electrolytes. Further, with many weak electrolytes, such as mesaconic acid,[1] α-chlorobutyric acid,[2] 2, 4, 5-trimethyl-benzoic acid,[3] and α-oximino-butyric acid,[4] to select a number of examples at random, the dissociation constant, as calculated by means of Ostwald's dilution law, is found to vary with dilution. Whether the degree of dissociation of these electrolytes is derived from the conductivity $\left(a = \frac{\Lambda}{\Lambda_\infty}\right)$, or from the freezing-point lowering, $a = \frac{d_o - d_t}{d_t(n-1)}$, where d_o and d_t represent the observed and the theoretical (on the assumption of no dissociation) freezing-point lowerings, the values calculated for $\frac{a^2 c^2}{(1-a)c}$ vary with concentration and deviate from the required constant. It is obvious, therefore, that either the dilution law does not correctly express the behavior of these electrolytes, or that the methods employed for the determination of their degree of dis-

* Communicated by Professor Creighton.

[1] White, G. F., and H. C. Jones, *Amer. Chem. Journ.*, **44**, 159 (1910).

[2] Lichty, D. M., *Ann. Chemie*, **319**, 369 (1901)

[3] Pfaff, A., *Dis. Heidelberg*, (1897).

[4] Hantzsch, A., and A. Miolati, *Zeitschr. physik. Chem.*, **10**, 1 (1892).

sociation gives incorrect values. This apparent break-down of the dilution law has been the subject of much discussion by Jahn, Arrhenius, and others, and opinions still differ widely [5] as to the cause of its inapplicability.

Since the dilution law holds for such a large number of electrolytes, and since its validity has been substantiated by thermochemical methods, solubility measurements, hydrolytic measurements, and measurements of reaction velocity, etc., it is probable that its failure, in certain cases, is due to the fact that the determination of the degree of dissociation by means of conductivity or freezing-point methods does not give correct results. The reasons for this are both physical and chemical. Variable friction of the ions; the existence in solution of interaction between the undissociated molecules and the ions, which counteracts their mutual independence;[6] the formation of inner complexes,[7] and the hydration of the ions [8] are all factors which tend to vitiate the values obtained from conductivity or freezing-point measurements for the degree of dissociation.

In view of the failure of conductivity or freezing-point measurements to give, in certain cases, correct results for the degree of dissociation, it is desirable to have recourse to other methods. Jahn [9] has attempted to determine the degree of dissociation by the measurement of concentration chains, but the method requires great precision and is hardly sufficiently sensitive where ordinary accuracy is required. Rothmund and Drucker [10] have determined the degree of dissociation of picric acid in aqueous solutions of different concentrations by measuring the distribution of the acid between water and benzene, and from the values obtained have shown that the value of the dissociation constant of picric acid varies slightly, but irregularly, with the concentration. On the other hand, the value for the dissociation constant of this acid is found to vary considerably with concentration, when values

[5] *Jahrb. d. Elektrochemie*, 8, 102 (1902), and A. A. Noyes, *Technology Quarterly*, 17, No. 4 (Dec., 1904).

[6] Jahn, H., *Zeitschr. physik. Chem.*, 33, 545 (1900); 35, 1 (1900); 37, 490 (1901); 41, 257 (1902); Nernst, W., *Ibid.*, 38, 487 (1901).

[7] Bredig, G., *Zeitschr. physik. Chem.*, 13, 262 (1894); Noyes, A., *Ibid.*, 36, 63 (1901); Steele, *Ibid.*, 40, 722 (1902).

[8] Blitz, W., *Zeitschr. physik. Chem.*, 40, 217 (1902).

[9] Jahn. H., *loc. cit.*

[10] Rothmund, V., and K. Drucker, *Zeitschr. physik. Chem.*, 46, 827 (1903).

for the degree of dissociation, obtained by conductivity or freezing-point methods, are employed.

In the present communication a general formula has been developed by means of which it is possible to calculate the ionic concentrations of an electrolyte in aqueous solution from data obtained from the measurement of the distribution of the electrolyte between water and some second liquid phase. In the development of this formula it has been assumed that in aqueous solution the electrolyte obeys the dilution law, and that, in accordance with Nernst,[11] there is a constant distribution coefficient for the undissociated molecules of the electrolyte between the two liquid phases.

THEORETICAL.

When a substance is shaken up with two non-miscible solvents it is distributed between them in a definite manner[12] which depends upon its solubility in each of the solvents. The distribution coefficient, the ratio in which the solute is distributed between the two phases, depends not only upon the solubility of the solute, however, but also upon whether the molecular complexity of the solute is the same in the two solvents. When the molecular complexity is the same in both solvents the distribution coefficient is constant for a given temperature; but when the solute has a different molecular complexity in the two phases the simple distribution ratio varies with the concentration at a constant temperature.

The symbols employed in the remainder of the paper are as follows:

c, the total concentration of the solute in the aqueous phase in normal moles per litre;

b, the total concentration of the solute in the second phase in normal moles per litre;

α, the degree of dissociation of the solute in the aqueous phase;

x, the degree of association of the solute in the second phase;

n, the complexity of the associated molecules in the second phase;

δ, the ratio, $\frac{c}{b}$, *i.e.*, the simple distribution ratio;

K_1, the ratio of the distribution of the normal molecules between the two phases;

[11] Nernst, W., *Zeitschr. physik. Chemie*, **6**, 36 (1890); **8**, 110 (1891).

[12] Berthelot, M., and E. Jungfleisch, *Ann. chim. Phys.* [4], **24**, 396 (1872); Jakowkin, A. A., *Zeitschr. physik. Chem.*, **18**, 585 (1895); Ostwald, W., *Lehrbuch*, 2. Aufl., 1, 811.

K_2, the constant governing the equilibrium existing between the normal and associated molecules in the second phase, and
k, the dissociation constant of the simple molecules in the aqueous phase.

If, at a constant temperature, a binary electrolyte is shaken up with water and a second solvent in which it dissolves with the formation of simple and associated molecules, then, after a short time, the following equilibria will exist:

(1) between the ions of the electrolyte and the undissociated molecules in the aqueous phase;
(2) between the normal molecules in the aqueous phase and the normal molecules in the second liquid phase;
(3) between the normal and associated molecules in the second liquid phase.

The first of these equilibria is governed by Ostwald's dilution law:

$$k = \frac{\text{anion concentration} \times \text{cathion concentration}}{\text{concentration of the undissociated molecules}} = \frac{a^2c^2}{(1-a)c}. \quad (1)$$

The second equilibrium is governed by the equation,

$$K_1 = \frac{\text{conc. of normal molecules in aqueous phase}}{\text{conc. of normal molecules in second phase}} = \frac{c(1-a)}{b(1-x)}. \quad (2)$$

The third equilibrium is governed by the equation,

$$K_2 = \frac{\text{conc. of normal molecules in second phase}}{\text{conc. of associated molecules in second phase}} = \frac{b(1-x)}{\sqrt[n]{bx}}. \quad (3)$$

Let the concentration of the undissociated molecules in the aqueous phase be z, *i.e.*, $c(1-a) = z$. Then from equation (2) it follows that

$$z = K_1 b(1-x), \quad (4)$$

and by combining equations (3) and (4)

$$z = K_1 K_2 \sqrt[n]{bx} = K_3 \sqrt[n]{bx}. \quad (5)$$

On multiplying equation (4) by K_3 and equation (5) by K_1, we obtain

$$K_3 z = K_1 K_3 [b(1-x)], \quad (6)$$

and

$$K_1 z = K_1 K_3 \sqrt[n]{bx}. \quad (7)$$

By adding equations (6) and (7),

$$z = \frac{K_1 K_2}{K_1 + K_2}\left[b(1-x) + \sqrt[n]{bx}\right], \tag{8}$$

$$= K\left[b(1-x) + \sqrt[n]{bx}\right]; \tag{9}$$

and for a second concentration,

$$z' = K\left[b'(1-x') + \sqrt[n]{b'x'}\right]. \tag{10}$$

By dividing equation (9) by equation (10), we obtain

$$\frac{z}{z'} = \left[\frac{b(1-x) + \sqrt[n]{bx}}{b'(1-x') + \sqrt[n]{b'x'}}\right]. \tag{11}$$

Therefore,

$$z' = z\left[\frac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}\right]. \tag{12}$$

On putting

$$p = \left[\frac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}\right], \tag{13}$$

equation (12) becomes

$$z' = zp\,. \tag{14}$$

Since in the aqueous phase the concentration of the anions or cathions is equal to the total concentration minus the concentration of the undissociated molecules, *i.e.*,

$$\alpha c = c - c(1-\alpha) = c - z,$$

equation (1) may be written

$$\frac{(c-z)^2}{z} = k = \frac{(c'-z')^2}{z'}, \tag{15}$$

or

$$\frac{(c-z)}{\sqrt{z}} = \frac{(c'-z')}{\sqrt{z'}}. \tag{16}$$

On substituting in equation (16) the value given for z' in equation (14), we obtain

$$\frac{(c-z)}{\sqrt{z}} = \frac{(c'-zp)}{\sqrt{zp}}, \tag{17}$$

whence

$$z = \frac{c' - c\sqrt{p}}{p - \sqrt{p}}\,. \tag{18}$$

On substituting in equation (18) the value given in equation (13) for p, we obtain

$$z = \left[\frac{c' - c\sqrt{\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}}}{\left[\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}} \right] - \sqrt{\dfrac{b'(1-x') + \sqrt[n]{b'x'}}{b(1-x) + \sqrt[n]{bx}}}} \right] \tag{19}$$

By means of the general equation (19) the concentration of the undissociated molecules in the aqueous phase may be calculated, even when the solute is present in the second phase as a mixture of normal and associated molecules. When association of the normal molecules in the second phase does not incur, *i.e.*, when $x = 0$, equation (19) reduces to

$$z = \frac{c' - c\sqrt{\dfrac{b'}{b}}}{\dfrac{b'}{b} - \sqrt{\dfrac{b'}{b}}}. \tag{20}$$

If, on the other hand, the association of the molecules in the second phase is complete, *i.e.*, if $x = 1$, equation (19) becomes

$$z = \frac{c' - c\sqrt[2n]{\dfrac{b'}{b}}}{\sqrt{\dfrac{b'}{b}} - \sqrt[2n]{\dfrac{b'}{b}}}. \tag{21}$$

It is evident from equation (19) that, when the solute is present in the second liquid phase as a mixture of normal and associated molecules, it is necessary that the degree of association, x, of the normal molecules be known, in order to calculate the concentration, z, of the undissociated molecules in the aqueous phase. The degree of association of the normal molecules in the second liquid phase may be obtained by means of measurements of the freezing-point lowering produced in the second solvent by the solute. The degree of association is given by the equation,

$$x = \frac{M_o - M_t}{M_o\left(1 - \frac{1}{n}\right)}, \tag{22}$$

where M_o represents the molar weight calculated from the observed freezing-point lowering, and M_t the molar weight calculated from the chemical formula of the solute.

EXPERIMENTAL VERIFICATION OF EQUATION (19).

In order to test the validity of equation (19), determinations have been made of the distribution of benzoic acid between water and benzene. Since it has been shown,[13] in the case of some electrolytes, that the distribution ratio varies with temperature, the distribution of benzoic acid has been measured at $6 \pm 0.1°$, a temperature which lies very close to the temperature at which the x values for benzoic acid in benzene have been determined by the freezing-point method.

Thiophene free benzene (*Kahlbaum zur Analyse*) was used in the distribution experiments. The benzene solutions of benzoic acid were mixed with an equal volume of "conductivity" water, and the mixture placed in suitable bottles, which were agitated in a thermostat for several hours, at the end of which time the bottles were removed from the agitation apparatus and allowed to stand in the thermostat until complete separation of the two liquid phases had taken place. Portions of the aqueous and benzene layers were then removed and analyzed with standard sodium hydroxide solution which was prepared from pure metallic sodium. Table I gives the results of the distribution measurements made with benzoic acid at 6°.

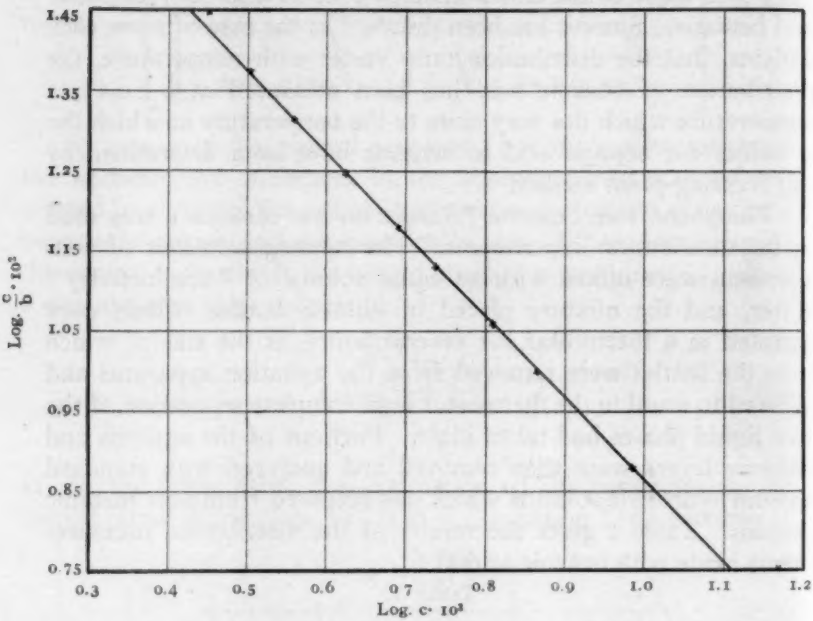
TABLE I.

No.	Concentration of benzoic acid in moles per litre		Simple distribution ratio
	Aqueous phase c	Benzene phase b	λ
1	0.00215	0.00754	0.2851
2	0.003291	0.01565	0.2103
3	0.004349	0.02750	0.1581
4	0.004930	0.03551	0.1388
5	0.005794	0.04951	0.1170
6	0.006440	0.06158	0.1046
7	0.007490	0.08352	0.0897
8	0.008743	0.1144	0.0764
9	0.009930	0.1480	0.0671
10	0.01139	0.1951	0.0584

[13] Hantzsch, A., and A. Vagt, *Zeitschr. physik. Chem.*, **38**, 705 (1901).

As the variation in the values of the simple distribution ratio in the foregoing table indicates, the benzoic acid exists partially as associated molecules in the benzene phase. The decrease in the value of δ with increase in concentration is linear, as is shown by the curve in Fig. 1, where the values of $\log c \times 10^3$ are plotted

FIG. 1.



on the axis of abscissæ against the values of $\log \frac{c}{b} \times 10^2$ on the axis of ordinates. With the exception of the values for the initial and final concentrations, all the points lie on a straight line.

In order to determine the degree of association, x, of the normal benzoic acid molecules in benzene, measurements were made of the freezing-point depressions of benzene produced by the same concentrations of benzoic acid employed in the foregoing distribution experiments. During the process of freezing, the solutions of benzoic acid were stirred by means of a platinum-iridium stirrer operated by an electromagnet.[14] The results of the freezing-point depression measurements are recorded in Table II.

[14] Beckmann, E., *Zeitschr. physik. Chem.*, **44**, 174 (1903).

TABLE II.

Concentration of benzoic acid		Freezing-point depression ° C	Observed molar weight M^o	Degree of association ($n=2$) x
Grammes acid per 100 grammes benzene	Moles acid per 1000 c.c. benzene solution at 6°			
0.2136	0.01565	0.049	218	0.881
0.3754	0.02750	0.085	221	0.896
0.4847	0.03551	0.109	222	0.901
0.6758	0.04951	0.151	224	0.911
0.8406	0.06158	0.187	225	0.916
1.1388	0.08352	0.251	227	0.925
1.5600	0.1144	0.341	229	0.934
2.0180	0.1480	0.439	230	0.939
2.6623	0.1951	0.574	232	0.948

The values for the observed molar weight, given in the foregoing table, agree excellently with those determined by Beckmann.[15]

TABLE III.

$$z=\frac{c'-c\sqrt{p}}{p-\sqrt{p}}.$$

No.	3	4	5	6	7	8	9	10
2	3.914	4.491	5.255	5.858	6.848	8.026	9.160	10.53
3	.....	4.593	5.227	5.791	6.819	7.980	9.125	10.53
4	4.026	.....	5.065	5.673	6.713	7.960	9.058	10.47
5	3.859	4.254	.....	5.658	6.770	7.938	9.087	10.51
6	3.828	4.259	5.057	.....	6.875	7.984	9.129	10.53
7	3.840	4.313	5.161	5.863	.....	7.918	9.073	10.51
8	3.830	4.318	5.154	5.803	6.743	.....	9.117	10.56
9	3.826	4.321	5.157	5.800	6.762	7.994	.....	10.61
10	3.833	4.337	5.175	5.806	6.788	8.018	9.183	.....

The concentration, z, of the undissociated molecules of benzoic acid in the aqueous phase may now be calculated by means of equation (19), from the data recorded in Tables I and II. Table III contains the values of z calculated by means of this equation. In the vertical columns, with the exception of the first, are represented the values of z which correspond to that total concentration, c, indicated by the numerals running horizontally along the

[15] Beckmann, E., *Zeitschr. physik. Chem.*, **2**, 715 (1888).

top of the table. The numerals in the first vertical column represent the concentrations, c', with which a particular concentration, c, has been combined in order to calculate z. The values given for z in Table III have all been multiplied by 10^3. The numerals 2–10, correspond to those employed in Table I.

If the relation between the undissociated molecules in the aqueous phase and the normal and associated molecules in the benzene phase is correctly expressed by equation (19), it follows that the values for z in each vertical column should be constant. Although the values for z in the different columns of Table III vary slightly, they are sufficiently constant to substantiate the validity of the equation. It should be pointed out that small variations in the values for c and b, as determined by analysis, produce relatively large changes in the values calculated for z. It is evident, therefore, that in order to obtain even approximately correct values for z it is necessary that c and b be determined with the highest possible degree of accuracy.

Values for the coefficient of the distribution of the normal molecules of benzoic acid between water and benzene at 6° are recorded in Table IV.

TABLE IV.

$$K_1 = \frac{c(1-a)}{b(1-x)} = \frac{z}{b(1-x)}.$$

No.	3	4	5	6	7	8	9	10
2	1.368	1.278	1.193	1.132	1.093	1.063	1.015	1.038
3	.....	1.307	1.186	1.120	1.088	1.057	1.011	1.038
4	1.408	.....	1.150	1.096	1.072	1.054	1.003	1.032
5	1.349	1.210	.....	1.093	1.081	1.052	1.007	1.036
6	1.338	1.215	1.148	.....	1.098	1.058	1.011	1.038
7	1.343	1.227	1.171	1.133	.....	1.049	1.005	1.036
8	1.339	1.228	1.170	1.122	1.076	.....	1.010	1.041
9	1.338	1.230	1.170	1.121	1.079	1.059	.....	1.046
10	1.340	1.234	1.174	1.133	1.083	1.062	1.017	.....
Mean.	1.353	1.241	1.170	1.119	1.084	1.057	1.010	1.038

As is to be expected, with the exception of the values for the third and fourth concentrations, the mean values for the coefficient of the distribution of benzoic acid between water and benzene are fairly constant. By taking the average of the mean values

in the foregoing table, the value 1.134 is obtained for the coefficient of distribution.

In Table V are given the values of the dissociation constant of benzoic acid, which have been calculated by means of Ostwald's dilution law from the values of c and z contained in Tables I and III. All the values in this table have been multiplied by 10^5.

TABLE V.

$$k = \frac{(c-z)^2}{z}.$$

No.	3	4	5	6	7	8	9	10
2	4.84	4.29	5.53	5.92	6.02	6.40	6.47	7.03
3	....	2.47	6.15	7.27	6.60	7.30	7.10	7.03
4	2.59	.....	10.49	10.37	8.99	8.86	8.39	8.09
5	6.22	10.72	.....	10.81	7.66	8.16	7.82	7.37
6	7.09	10.57	10.74	....	5.50	7.22	7.03	7.03
7	6.75	8.83	7.76	5.68	....	8.60	8.10	7.37
8	7.03	8.68	7.95	6.99	8.27	....	7.25	6.52
9	7.15	8.58	7.87	7.06	7.84	7.02	....	5.72
10	7.11	8.11	7.41	6.92	7.26	6.56	6.08	....
Mean.	6.10	7.78	7.11	7.63	7.27	7.52	7.28	7.02

It will be seen that the calculated values for k in each column of Table V vary slightly and irregularly about the mean value. By taking the average of the means, the value 7.2×10^{-5} is obtained for the dissociation constant of benzoic acid in water at 6°. By means of electrical conductivity measurements, White and Jones [16] have found that the dissociation constant of benzoic acid in water is 6.2×10^{-5} at 0°, and 6.7×10^{-5} at 15.8°; while Salm [17] obtained the value 7.2×10^{-5} at 18° by a colorimetric method. It is evident, therefore, that, while the method described in this paper gives a value for the dissociation constant which is somewhat higher than that obtained by the conductivity method, the agreement between the values obtained by the two methods is sufficiently close to demonstrate that approximate values for the dissociation constant may be calculated from the distribution data by means of the formula derived in this paper. Although the distribution method for the determination of the dissociation

[16] White, G. F., and H. C. Jones, *Amer. Chem. Journ.*, **44**, 159 (1910).
[17] Salm, E., *Zeitschr. physik.Chem.*, **63**, 83 (1908).

constant of electrolytes cannot compete with the conductivity method in most cases, on account of the relatively large experimental errors involved and the high degree of accuracy necessary, its use is suggested in those cases where the value of the dissociation constant of an electrolyte, as determined by the conductivity method, is found to undergo considerable variation with change in concentration.

SUMMARY.

1. A general formula has been developed for the calculation of the concentration of the undissociated molecules of an electrolyte in water by means of data obtained by the measurement of the distribution of the electrolyte between water and a second liquid phase. The formula takes into consideration the possibility of association of the electrolyte in the second liquid phase.

2. In order to test the validity of the formula, measurements of the distribution of benzoic acid between water and benzene have been carried out at 6°, and, from the data obtained, the concentration of the undissociated molecules of benzoic acid in the aqueous phase has been calculated. From these values, a mean value, 7.21×10^{-5}, has been obtained for the dissociation constant of benzoic acid in water at 6°.

3. Although the foregoing value for the dissociation constant of benzoic acid in water is somewhat higher than that obtained by the conductivity method, the use of the distribution method for obtaining an approximate value for the dissociation constant of an electrolyte, in those cases where the value as determined by the conductivity method varies considerably with concentration, is suggested.

DEPARTMENT OF CHEMISTRY,
Swarthmore College,
Swarthmore, Pa.,
May 24, 1915.

CONDITIONS AFFECTING THE SUCCESS OF MAIN LINE ELECTRIFICATION.*

BY

W. S. MURRAY,

Consulting Engineer, New York, New Haven and Hartford Railroad Company.
Member of the Institute.

DISCUSSION

MR. ALFRED W. GIBBS (*Chief Mechanical Engineer, The Pennsylvania Railroad Company*).—While recognizing the merit of the paper and its frankness throughout, I call attention to a few points where it is not sufficiently explicit, or with which I do not agree.

As for the first, I allude especially to the tendency of cities to require electrification through their limits, usually for the purpose of eliminating smoke. While it is true that the inhabitants of a small community may be as much inconvenienced as those of the largest city, it must be recognized that this demand, if fully carried out, means the establishment of as many steam locomotive terminals as there are separate lines of road leading into the city, the alternative to this being the electrification of the whole line. These local terminals would involve not only a heavy capital outlay, but a continued charge to expenses, due to the increased cost of the additional organizations and the less efficient use of the labor and equipment. This is properly a charge to electrification, and a heavy one.

Mr. Murray is not quite fair in his criticism of the engineers who are responsible for the introduction of the direct-current system into the large terminals in New York City. It must be remembered that a long period of agitation had preceded the determination to electrify. The electrification was to avoid the objection to steam operation into the heart of a great city, and the first condition was that it should be a success from an operating standpoint. Is it surprising that the engineers in charge should turn to methods which had been thoroughly tried out? In at least one case the proposal to adopt the alternating-current system of transmission was not seriously advanced until after a very large outlay had been incurred for direct-current operation,

* Concluded from page 557, May issue of this JOURNAL.

a large part of which would have had to be absolutely thrown away to introduce the new system—and that untried on a large scale in this country. It must be remembered, further, that any serious operating failure would have jeopardized the whole investment and put back electrification for years. The engineers did not then have to settle the question of future extension of electrification. There was not then, and there may not be for a long time, any necessity to consider the question of future road electrification. By that time the air will have cleared considerably. It must be admitted that the operating results in New York have fully justified the engineers responsible.

I criticise, also, the statement that one pound of coal burned under the boiler of a central power plant will develop twice the drawbar power that the same amount of coal will produce when burned in a locomotive firebox. Proper allowance has not been made for the improvement in the modern steam locomotive with more liberal boiler capacity and with superheat. As an example, I have a record of coal per drawbar horse-power for 27 tests of one locomotive on the locomotive testing plant at Altoona. It shows:

2.5 to 3 pounds	12 tests
3 to 3.5 pounds	7 tests
3.5 to 4 pounds	3 tests
4 to 4.5 pounds	1 test
4.5 to 5 pounds	4 tests

These are the rates when running, added to which are certain standby losses at terminals.

The figures for the coal per kilowatt-hour at Cos Cob, as given by Mr. Murray, when reduced to drawbar horse-power for the locomotive, do not justify the statement of relative efficiency.

There is great difficulty in arriving at a fair basis of comparison between steam and electric operation. For road locomotives and through electric operation the problem is the simplest. For switching service, where the steam locomotive may waste more steam at the safety valve that it uses in the cylinders, the problem is very different. This part of the paper covers one of the greatest advantages of the electric operation.

In the table giving the cost of power the total costs are not given. Operation and maintenance account for 0.511 cent; fixed charges, including taxes and insurance, amount to 0.180 cent.

No allowance is made for depreciation in the form of obsolescence in the power-house and its equipment. From data of somewhat similar power-houses, I should say that the fixed overhead charge, including depreciation, would be nearly double the figure given, say 0.35 or 0.4 cent, in the inverse ratio to the output. I regard this part of the expense account as a most important part of the accounting; otherwise, the time comes with startling suddenness when you have obsolete equipment, with insufficient reserve to replace it.

While making these criticisms, it is but fair to recognize the courage of those responsible for the electrifications described in this paper and preceding ones.

The paper is, in my judgment, very instructive, and all the more so because no claim is made for the 100 per cent. perfection which we never realize.

MR. GEORGE R. HENDERSON (*The Baldwin Locomotive Works*).—Mr. Murray's paper on Main Line Electrification will stand out as a "classic," giving, as it does, actual figures for cost of operation on an alternating-current line. Several years ago Mr. W. J. Wilgus gave similar data for the direct-current lines of the New York Central. Both of these papers show that "uniformity" of traffic is just as important as "density" of traffic, otherwise the overhead charges of the power plant, which must be abnormally large, will more than "eat up" any saving due to fuel consumption, repairs, and labor, as the plant must take care of *peak loads*, and these can only be "smoothed out" when the traffic is uniform. As one hundred dollars per kilowatt will hardly cover power-house and transmission lines, the importance of this observation will be obvious.

The fuel saving is stated as 50 per cent. for a fixed drawbar pull, yet it must be borne in mind that this comparison is made with the old type of saturated steam locomotives, and modern steam engines, fitted with superheaters, will reduce this ratio very considerably, say to 65 per cent. the amount of coal for such a locomotive as would be built to-day.

The fact that electric locomotives cost about three times as much as a steam locomotive of similar power must not be overlooked, also the flexibility of service of the latter is very important, as it may be transferred to any division desired owing to

traffic conditions, and is not tied to a particular section whose limits are the lengths of the conductors leading from the power-house. This is of prime importance to roads carrying intermittent business, such as live stock, which may have a week's work consolidated into a single night, or on the ore ranges in Michigan, which deliver cargoes to lake boats only during the period of navigation. Under such conditions the overhead charges would be out of all proportion to the work accomplished, and the electric locomotives would be idle a large part of the time, as they could be used only on electrified divisions.

However, we are glad to note that Mr. Murray does not wildly and enthusiastically proclaim electrification a "sure cure" for all evils, regardless of environment and operating conditions, as did some electrical experts a few years ago, and the conservatism for which he pleads will surely benefit the whole problem of electrification, by insuring the large expenditures chargeable to capital only where they will produce remunerative returns from operation.

MR. E. H. MCHENRY (*McHenry & Murray*, Engineers, New Haven, Conn.).—Mr. Murray strikes a very important key-note in the opening paragraphs of his interesting paper, in referring to the two-fold necessity for satisfying the requirements of both the public and the railroad as the touchstone of success.

The first requisite in the interest of the public may be fairly claimed as already satisfied, but the greater task of insuring adequate returns to the railroads upon the large capital investments required for conversion from steam to electric traction is as yet far removed from the state of an exact science. As stated by Mr. Murray, there are many places where electric traction could now be installed with profit, but the ability and ingenuity of the engineers will be taxed to the utmost degree in further widening and enlarging the present commercial field of application. The progress of recent years in the development of the art all tends in the right direction, as with experience and a clearer perception of the governing principles, the commercial efficiency of the invested capital grows greater, and there is no reason to doubt that the past progress will be continued in the future, with the result of greatly extending the present limits. With the growing tendency toward the consolidation of the best features of all the divergent

systems into one system of greatest combined merit, the so-called war of the systems is already nearly at an end, and even now it will be found that there is more to be gained by a study of the possibilities afforded by the new method of train propulsion in securing the closest adaptation of its many points of merit to the operating requirements than by any probable difference between rival systems. There is room for much optimism in this general direction, although many cases will arise of special difficulty, in which the community or that part of the public most benefited by the improved facilities are least able or least willing to pay the cost of the service, as in the case of communities using costly passenger terminals, and unless some satisfactory method can be devised for spreading the cost of such service over a city or a state substantially in the form of a tax, no practical solution of this difficult problem will be clearly apparent. In electrification, as in all other branches of engineering, the highest art will be shown by " the ability to make a dollar earn the most interest."

MR. C. RENSHAW (*Westinghouse Electric and Manufacturing Company*).—As a traveller climbing a mountain will often not realize the height he has attained until, pausing, he looks back over the route he has traversed, so, although from the beginning I have followed the New Haven electrification through its various stages, the summary which Mr. Murray gives of the electric mileage, equipment, and activity to which the road has now attained has impressed me particularly.

The application of electricity to the operation of every class of passenger, freight, and shifting service on an entire engine division of one of the busiest trunk line railroads of the country is an achievement that stands without a parallel in the entire world. It should be particularly gratifying, not only to those who are interested in electrical matters, but to the general public as well, that the undertaking is proving an economic as well as a technical success.

No less notable than the achievement itself has been the policy of the railway company in giving so freely to the engineering public the full results of its investigations and experience, not only with regard to its successes, but—what is of perhaps greater utility and certainly of greater rarity—with regard to its difficulties. The costs and other data which Mr. Murray has included in this paper

form a valuable addition to the previous contributions which he has made.

As might be expected from experience with any original enterprise, Mr. Murray estimates that the electrical plant of the New Haven road, with the ten years' experience in construction and operation, now available, could be reproduced to-day for not more than 60 per cent. of its original cost. It should be gratifying to all, however, that he also states the financial return will ultimately be sufficient to justify the actual expenditure to date, so that the courageous pioneer will not be a loser. Some road, he says, had to make the first break into the dark, but, from the data assembled, future results in the application of electricity in heavy trunk line territory can be predicated on assembled facts and not predicted from hypothetical analysis.

In considering the economies over steam operation, by means of which electrification can justify the investment which it requires, Mr. Murray puts the matter very simply by pointing out that these economies are normally of three kinds; *i.e.*, saving in fuel, saving in motive power maintenance and repairs, and saving in train miles.

Broadly speaking, he says the costs of the first two items under electrification will be one-half the cost under steam operation. The saving in train miles, however, depends very largely on local conditions and cannot well be generalized. Success in electrification, therefore, is primarily dependent upon density of traffic. This reduces the matter pretty well to its lowest terms and should help eliminate some of the mystery with which the savings to be effected by electrification have apparently heretofore been surrounded in the minds of many railroad operating officials.

A detail in the paper which deserves particular comment is the fact which is pointed out that an electric locomotive, like an over-willing horse, may work itself to destruction if permitted to do so. While it is perfectly possible to keep the cost of maintenance and repairs at one-half those of steam locomotives, under conditions most favorable to steam operation, Mr. Murray says it is only by the most rigorous and careful inspection and conformity to proper rules of operation that this can be done.

This fact is one of the most difficult to impress upon the minds of steam railroad operators, and it is to be hoped that the figures of 8.6 and 10.6 cents per mile for the maintenance and repairs of

the general average of New Haven locomotives, as compared to the average of 3.96 cents per mile for the ten locomotives which have been properly overhauled, will have some effect in bringing about a more thorough realization of this important matter. Incidentally, this figure for the maintenance and repairs of ten locomotives, making 466,524 miles in the seventh year of their age, is a remarkable commentary on the reliability of such equipment when handled intelligently.

The paradoxical action of heavy freight trains in steadying the power-house load instead of causing an increase in the peaks, as it was feared they would do, is also of interest. The fact that these trains, by dropping the voltage slightly, when drawing heavy accelerating currents, naturally cause other trains moving at high speed in the neighborhood to automatically reduce their power requirements, is readily appreciated when once noted, but is one of the many items brought out by actual experience which are often overlooked in advance calculations. Fortunately, in this case the unforeseen item is one which produces a favorable rather than an unfavorable effect on the operation of the system.

Many other items which Mr. Murray has set forth are also worthy of comment, and the entire paper forms a valuable contribution to the subject. We hope that it may serve as an inspiration to other engineers in active touch with the operation of similar properties to present their experiences with equal freedom for the general benefit of the art.

MR. F. E. WYNNE (*Westinghouse Electric and Manufacturing Company*, East Pittsburgh).—Mr. Murray's paper is a very valuable contribution to the literature of electric railroading, not only on account of the operating data which it contains, but because of its clear exposition of the broad principles to be considered in deciding whether an electrification will be successful. In the past electrical engineers have been accused (and to some extent rightfully so) of advocating wholesale electrification of steam railroads without regard to the measure of success which might be expected. It is therefore very pleasing to find a representative electrical engineer taking the stand that an electrification is only justified when it is an assured success from the standpoint of all parties concerned.

The figure of $15,000,000 given as the expenditure for elec-

trification of the New Haven Railroad to date indicates that the expenditure has been $120,000 per unit of motive power and $30,000 per mile of single track. Complete electrification of the New York-New Haven Division will be accomplished without additional expenditure for trolley construction (which is a very large proportion of the total), and consequently these unit figures will be somewhat changed. The total expenditure per unit of motive power will gradually decrease and that per mile of single track will increase to some extent because of the larger number of electric engines in service without increase in the mileage of the electric zone.

The further statement that the present plant could be reproduced at the present time with better operating results for not more than 60 per cent. of the actual cost to date indicates that for an installation similar to the New Haven the total cost may be made less than $70,000 per unit of motive power, while the cost per mile of single track will be in the neighborhood of $20,000. These figures, as noted by Mr. Murray, represent the cash outlay, and in determining the net cost of electrification they will be reduced by the credits for steam equipment replaced, etc.

The figures given for mileage show that passenger locomotives average approximately 170 miles each daily, and that only 22 per cent. of the total number of passenger trains have the full run of seventy-three miles. This daily mileage per locomotive is comparable to that secured from electric cars operating in rapid transit and heavy interurban service. It therefore seems reasonable to assume that when all through trains are electrically operated the average daily mileage per locomotive may be materially increased.

Similarly the multiple-unit motor cars show an average of eighty-four miles each daily. This is relatively low, but is undoubtedly due to the fact that local trains are bunched in the morning and evening rush hours to a greater extent than is ordinarily found. This low mileage, together with the fact that over half of the total multiple-unit trains operate with only one trailer per motor car, indicates that the railroad is not yet getting the full benefit of the rather large equipments on the motor cars.

The figures given in connection with the operation of the

switching engines illustrate the remarkable reliability and operating economy of electric locomotives in this particular class of service. Such results lead us to believe that the field for the electrification of railroad yards is a large one and that considerable progress in this direction will follow a full appreciation of the success which may be expected. As density of traffic is one of the largest factors in determining the advisability of electrifying main lines, so the desirability of yard electrification will largely be determined by the degree of congestion existing. In such installation the initial expense may be reduced to a minimum where central station power is available.

Mr. Murray states that electrification very quickly increased the reliability of operation to some three or four times that of the steam operation it replaced. We do not altogether understand what is the measure of reliability used in making this comparison, but assume he means that the number of failures were from one-third to one-fourth as many as were encountered during steam operation for a similar period.

In connection with Mr. Murray's statement that maintenance and repairs on electric locomotives amount to approximately one-half those required for steam locomotives with equal weight on drivers, I should like to ask whether operation in equal service also should not be part of the basis of comparison.

The remarks regarding the differences in the natures of electric and steam engines are particularly pertinent, and Mr. Murray's plea for electrically-trained men in the administrative department of electrified steam railroads points out one of the things which is of the highest importance in securing the fullest measure of success in electrifications.

It is interesting to note the results secured in connection with energy consumption, as these closely check the accuracy of calculations made in connection with this service, thus illustrating the fact that the energy consumption with electric operation can be very closely predetermined where trains are operated on a steam railroad basis; that is with definite schedules and definite stops. The figures given show further how rapidly the consumption of energy increases with the increasing number of stops as indicated by the several classes of service. Since the electrical equipment is merely apparatus for converting electrical into mechanical energy, it follows that with increased unit energy consumption

increased work is required of the electrical equipment, and therefore electric locomotives will safely handle much greater tonnages in through service than in local service. They will also handle greater tonnages at moderate speeds than can be operated at high speeds.

The information regarding the improvement of load factor and smoothing out of the curve of power station output with the addition of trains (even though those trains were comparatively heavy) illustrates a principle which has been found to exist in connection with city and interurban electric railways; namely, that the peak load on the system increases less rapidly than in proportion to the increase in number of cars or trains operated. However, in city and interurban systems this is probably due more to the fact that as the number of cars operated increases a smaller proportion of the total are starting simultaneously, rather than to the fly-wheel effect of the moving cars. We are inclined to the opinion that with further increase in the number of trains electrically operated by the New Haven Railroad some benefit in the improvement of load factor and reduction of peaks will be secured from this source, as well as from the fly-wheel effect of the moving trains.

The reduction in cost of the trolley construction which has been made since the initial installation shows great progress in the right direction. However, we believe that it is not yet sufficiently low to represent maximum all-around economy. This belief is strengthened somewhat by Mr. Murray's statement of the extraordinary reliability of the overhead construction in stormy weather. This great degree of reliability leads us to question whether part of the cost of the overhead construction may not be due to its being designed with an unnecessarily great factor of safety.

In connection with Table 17, only interest, taxes, and insurance are specified as fixed charges. I should like to ask whether a depreciation allowance is included in the figures given.

I feel that the Institute is to be congratulated upon securing the presentation of such an able paper, and trust that its author may continue to make public his valuable data regarding the principles of railroad electrification, to the end that electric operation of steam railroads may be extended and may be attended by the greatest success.

PHILIP TORCHIO (*New York Edison Company*).—The growth of large electrical undertakings has been the evolution from small beginnings. In the case of railroad electrification, however, the problem has been quite different. With an established heavy traffic which does not allow of interruption or delays, a new system of traction is to be substituted, requiring radical structural changes all along the line and an entire new system of power generation and distribution.

The engineers confronted with the problem have attacked it in a comprehensive and thorough manner, developing complete systems as self-sustaining and autonomous as the progress of the art allowed them to accomplish at the time. Mr. Murray has described the operation of a system which really went a step further and anticipated the progress of the art by many years. The importance of this epoch-making "experiment" is naturally immensely valuable.

The author emphasizes the point that the experience of the New Haven will benefit the other railroads in solving their problems of electrification. In this connection I wish to call attention to the item of investments in power-houses and power-transmitting lines, which in all the original electrifications were assumed as a necessary part of the equipment, but which in late years the railroads have found more economical to omit from their investment, substituting purchased power delivered to them by central-station power companies. The New Haven has purchased from The New York Edison Company all the power required for its western section of the alternating-current lines and terminals. The Pennsylvania Railroad has purchased from the Philadelphia Electric Company the power for the electrification of its main line from Philadelphia to Paoli and for its other contemplated extensions around Philadelphia. The London, Brighton and South Coast Railway Company buys current from the London Electric Supply Corporation, Ltd. The Chicago, Milwaukee and St. Paul Railway and the Butte, Anaconda and Pacific Railway buy power from the Montana Power Company.

Along every large railroad where the heavy traffic would warrant electrification there is, or can be made readily available, abundant supply of electrical power from power companies. These companies, by averaging the power demand from a great diversity of users, reap economical advantages in investment and

in generation and distribution of power which the railroad cannot secure under independent generation. I wish to call attention to this phase of the problem, as the saving in investment in stations, substations and transmission lines may represent a sensible item in the investment of railroad electrification.

The central stations, besides offering investment and operating advantages, can furnish, in addition, a more reliable supply of power, because they command the best knowledge of the art of electricity supply, which is their exclusive and specialized business.

W. A. DEL MAR (*New York City*).—This paper is interesting not only as a statement of operating results with the single-phase system of traction but also as a basis of comparison between steam and electric traction. Indeed, so nearly equal are the principal electric systems from an economic point of view that we may well afford to neglect their rivalry in view of the more vital rivalry between steam and electricity. I believe that the "battle of the systems" was largely caused by the advocates of each system being so carried away by enthusiasm as to be unable to tell the whole truth, whether in defending their own or criticising the others. Here, at last, we have a presentation of operating results, making it unnecessary to base conclusions upon specious arguments about details.

It is unfortunate that the operating costs are given for only two months of the year. The results would have been more valuable if they had been based upon a complete year, as it is almost impossible to select two really representative months, especially in view of inevitable variations of maintenance costs of equipment. The omission of the annual fixed charges is also to be regretted, as it is well known that the running charges can be made less with electric than with steam traction, but it is not always clear whether the fixed charges added by the electrical plant will destroy the favorable balance due to operating economies. Various cost data are presented, but in such form as not to be available for calculating fixed charges. We do not know, for example, whether the $15,000,000 expenditure mentioned by Mr. Murray includes the cost of reducing telephone disturbances and of altering the right-of-way to conform with electrical requirements.

One cannot help being appalled at development charges

amounting to forty per cent. of the entire investment, as one would infer from Mr. Murray's statement that the present system could be replaced for sixty per cent. of the original investment. An interesting feature about the installation has been the development from the complex to the simple in mechanical details, and *vice versa* in the electrical features.

Examining the operating costs with the view of comparing them with steam operating results, one is confronted by a series of questions which, if unanswered, will render such comparison difficult. Having gone to great trouble to segregate and clearly present the operating costs, Mr. Murray proceeds to obtain unit costs by dividing these operating costs by car mileages and train mileages of unspecified nature. It is to be hoped that Mr. Murray will state the nature of the mileages with greater detail, particularly as to whether they include yard switching and light locomotives. These two items may easily amount to fifteen per cent. of the entire milieage.

The fixed charges given for the Cos Cob power station appear to be very low. It would be interesting to know whether they include depreciation.

An interesting feature of the New Haven installation is the use of meters on the locomotives. This enables an intelligent estimate to be made of the relative cost of different classes of service, such as passenger locomotive, freight, and multiple-unit. Meters on locomotives are not very accurate, due to vibration, but it is interesting to note that, provided the vibration is impartial with respect to making the meters read high or low, the probable error in the aggregate reading will be quite small, due to the large number of locomotives. Thus where there are 100 locomotives a possible error of twenty per cent. in each meter will cause a probable error of only $\frac{20}{\sqrt{100}} = 2$ per cent. in the total.

Electric railway men should feel very grateful to Mr. Murray for this paper, which will long be consulted as a classic upon a great engineering topic.

MR. R. H. WHEELER (*Assistant Electrical Engineer, Mackenzie, Mann & Co., Ltd.*, Montreal, Canada).—In this paper there comes a boon to those interested in the application of electricity to train movements in the practical definitions of condi-

tions which affect the success of a railroad electrification, supplemented by copious data resulting from an extended period of operation. The haze from the "shots" of the "battle of systems" now clears away from the single-phase side of the field, showing an interesting array of results achieved.

Two points, from the many ably put forth, appeal to me for special emphasis. These are vital to the success and quantity of success, which latter is the chief "lure" of electrification.

First.—The careful analysis and choice of a form of electric power which may be standardized for all classes of train service on that road.

Second.—The "inheritance" to electric operation of "steam-trained" operators.

Under electric operation the power plant is separated from the locomotive, and it is evident that the economy of energy transmission, from its source to the wheels of the engine, is paramount. The overhead contact wire lends itself very readily to this transmission duty, in yards, terminals, on the road, and elsewhere. For reasons of high economy of transmission and diversity of transformations, Mr. Murray suggests that this wire be energized with 11,000 volts single-phase, 25-cycle power. By the use of the mercury-arc rectifier the admirable qualities of the series direct-current motor can be retained. This motor is especially desirable where the "density of traffic" factor is highest, as in suburban and terminal electrification, on account of its accelerating capabilities and weight economies, both in itself and its control. However, to carry about a rectifier upon the class of equipment employed in terminal service, even if rectified single-phase current were suitable, would impose a serious handicap in both weight and control complication. Rectified single-phase current is not ideal for direct-current motors of the usual design, requiring increased thermal capacity and thus weight. These reasons militate against the "standard" proposed as suitable for all classes of train service.

However, by placing the rectifier in the roadside substations and taking advantage of the economies and freedom of disturbance to other local circuits of a balanced three-phase, sixty-cycle supply, another "standard" results which supplies, over the overhead contact wire, power at 3000 volts direct current, and

which has the desired essentials of transmission economy and standardization of motive power equipment. In the case of heavy grade divisions operated by rectifier substations, engines arranged for regeneration would be employed. This second "standard" is offered to emphasize Mr. Murray's definition of the successes arising from a choice of energy which can be standardized. A railroad which, in its initial electrification, utilizes a system which is capable of being extended through successive increases of electrically-operated territory has gone far to ensure successful electrification.

With the figures Mr. Murray presents, indicative of the successful operation of the New Haven motor cars and A. C.-D. C. engines since the last overhaul in a well-appointed maintenance shop, it is evident that the straight alternating-current engines will show greater economies. When the data are available from the Butte, Anaconda and Pacific Railroad, Chicago, Milwaukee and St. Paul Railroad, and Canadian Northern Railway giving results of operation, especially as the latter is to employ 2400-volt motor cars, another decisive step towards standardization can be made.

Secondly, I wish to emphasize the importance that "heredity" plays. Mr. Murray states that a thorough understanding must be had of the fundamental differences of steam and electric operation. Electric operation is a more exact science than steam operation, since a great many of the variable factors are removed. Chief of these, the power generating plant, is removed from the hands of the fireman, and he cannot now produce more power to get an overloaded engine over the road. Certain rules and axioms the officials of the operating department must appreciate in their adapting themselves to the era of electrification.

As well, the proper care and thorough inspection of electric equipment should be insisted upon and the long life resulting from renewals and not repairs be gained. It takes thorough investigation and time to care for such equipment, and in the early stages a little more lee-way should be given the shopmen. Coöperation in these things will produce the economies which make an electrification successful.

CLOSURE BY THE AUTHOR.

The writer takes this opportunity of expressing his appreciation of the many interesting points and suggestions that have been brought out in the discussion of the paper.

Before specifically commenting on the individual discussion, the writer desires to draw attention to an (apparent) error in the paper, which appears in Table 17, page 551 (May issue), under the statement covering the output of the Cos Cob Station. In that statement the fixed charges are named as 1.8 mills per k.w.h. This statement is based upon certain discounts allowed by the railroad company on installation charges, and also does not include depreciation. For outside comparative purposes, however, the rate of 1.8 mills should be changed to 2.9 mills, the latter figure being based upon an eleven per cent. rate on the total investment involved, carrying with it interest, insurance, depreciation, and taxes. The total cost, therefore, for current would become 8.01 mills per k.w.h. instead of the rate named in the paper of 6.91 mills, the former and larger figure being then in form as previously stated for comparative purposes.

I am indebted to Mr. H. P. Davis, vice-president of the Westinghouse Electric and Manufacturing Company, for his valuable discussion, and it is hardly necessary for me to point to the fact that not a little of the success in the application of high-tension alternating current to heavy traction systems is due to Mr. Davis. In particular are we indebted to Mr. Davis for the system of control that is used for electrical sectionalization, and, while the New Haven system now in service has been modified considerably to conform to the rearrangement of its circuits to reduce to a minimum electromagnetic induction, the earlier and basic elements which were worked out largely under the suggestion and coöperation of Mr. Davis are found in the system now controlling our entire lines.

Mr. Davis's long connection with the development of heavy electric railway equipment lends authority to his voice in commenting on the proper treatment which should be accorded electrical equipment. It might be said of electrical as compared to steam equipment, that *it is possible to get twice as much out of it and it is four times as different,* and the brains and fingers that are to handle the electrical equipment should have an electrical rather than steam instinct governing them, for the rapid progress

and success of the application of electricity to heavy traction railways will largely depend upon the recognition of these simple facts.

Of the various departments of a railroad, covering respectively Executive, Traffic, Transportation, Legal, Operating, and Engineering matters, it were natural and seemingly logical to assign an electrification problem to its Engineering Department, and yet the advance of the art in the application of electricity for heavy traction purposes has been so rapid that I venture the opinion that ninety per cent. of the chief engineers of all the roads in this country, being so perfectly unacquainted with the underlying principles of the generation and application of electricity, would shrink from such a responsibility. It is to be noted that a few roads have placed their Engineering Department under the jurisdiction of their Operating Department, under which arrangement an assignment of the problem to the Engineering Department jeopardizes still further the desired result. The railway company will do well, therefore, when it decides to make so radical a change in its motive power, involving millions of dollars, to assign that responsibility solely to a man qualified to assume it, and also to see to it that his hands are not tied by having to report to officers in the Engineering and Operating Departments, who are unacquainted with the governing principles of electricity; indeed, on the contrary, it is my opinion that these departments should be requested by the president to coöperate to the full with the officer responsible for the work, thus clothing rather than robbing him of the authority so essentially necessary in producing an *electrical* plant to accomplish an *electrical* result.

As the above is true in the matter of electrical engineering and construction, it is to a very great extent true in the matter of operation, and, as pointed out in the paper, while no radical change is necessary in the general railroad organization of to-day, I cannot too greatly emphasize the absolute truth that when a railroad company has adopted electricity to be its motive power the operating officials should state the *schedules* and *consist* of trains, and then abide by the decision of the electrical officer (whose duties might be defined as " in charge of electrical engineering and construction and the features of electrical operation ") as to what power, both generative and motive, is necessary.

In the past there has been an appalling attitude on the part

of officials of some steam railroads electrifying—rather than welcoming the selection of electrically-trained men for positions such as superintendents of electrical shops, road foremen of electric engines, master mechanics for electric engines, to insist that these positions be filled by men who have occupied seemingly analogous positions under steam locomotive conditions, notwithstanding their past environment, experience, and adaptability to the new and different conditions confronting them make them unfit, both from a safety and economic standpoint, to serve. Railway managements are now waking up to these facts, and in the last year great improvement in the electrical *personnel* of the operating departments has resulted. There is much along these lines to be accomplished yet, and dire necessity has as much as anything brought about the real and final awakening of a differentiation between electrical talents that apply and those of steam that do not. This information is too vital, and, indeed, as it constitutes the very rivets and gusset plates of the electrification bridge over which we are crossing to more economic, safe, and satisfactory railroading, it has a fitting place here. It has been a strenuous past; the bills have all been paid, and as sure as they represent the millions of dollars lost in the past, so do they equally represent the millions of dollars to be saved in the future, and so at least we can say it has taught us "how not to do it."

Referring to Mr. McHenry's comments: It has always seemed to me that electrification has been an advantage to "the many" at the expense of "the few." While it is true that electrification for *economy's* sake bids fair to preëmpt the use of it for *necessity's* sake, still it is fair to believe that the consideration of electrification of city terminals carries for the present a more popular justification, and if it can be proved beyond doubt that the electrification of city terminals imposes a financial burden upon the railroad, it would seem to me that Mr. McHenry's suggestion of an "outside" tax should find justification.

In Mr. George R. Henderson's valuable contribution to the paper an excellent point is made with regard to the uniformity of traffic being a most important adjunct in securing the economies of electrification. In nearly all the situations of electric power generation and distribution we seldom, if ever, hear of one wherein a one hundred per cent. load factor obtains. There are

thus certain hours in a day, and in railroad work generally two (if only the passenger service is operated by electricity), when the power requirements are at a maximum. It is thus seen that at all other times of the day and night full advantage is not being taken of the total electrical investment. Realization upon Mr. Henderson's suggestion is to a large measure accomplished by the electrical movement of freight as well as passenger, as the maximum power demand for the former can be made to follow at the time of minimum demand for the latter. Those who have studied the matter of load factors in their application to lighting and street railway properties have accustomed themselves to such figures as from thirty-five per cent. to forty-five per cent. and sometimes reaching fifty per cent. load factor. I have no doubt it will be of interest to state that in plotting the combined load curves of the New Haven passenger, freight, and switching services without any rearrangement of the schedules as they are made up to-day a load factor of seventy-five per cent, is secured, which figure, I am sure Mr. Henderson will agree, bespeaks the uniformity of the density of traffic at least in the New Haven case. It is apparent, therefore, that in the study of electrification equal consideration should be given to both freight and passenger movement.

With regard to fuel saving, if the economy of generating units remained fixed, it would be fair to grant Mr. Henderson's point with regard to the change of ratio from fifty per cent. to sixty-five per cent. On the other hand, the thermal efficiency of generating plants is easily keeping pace with that of steam locomotives, and, granting this, there are no other constants or variables which will tend to alter the ratio of one or two in favor of the fuel economy of drawbar pull by central electrical stations *versus* steam locomotives.

Mr. Henderson's point with regard to the transfer of steam locomotive power to different divisions of a road where congestion may require is interesting; I can conceive, however, of a division electrifying, with economy, not inclusive of the financial credits due to the steam locomotives replaced, thus automatically providing steam locomotives for service in the congested districts. The principal value of Mr. Henderson's observation on this matter to me is in pointing out that every electrification is a study in

itself, and in electrifying one division its effect may be felt in many different ways in other divisions.

I am indebted to Mr. F. E. Wynne for his unit analysis of investment cost. I think that he has transformed electrification investment into a very unique and interesting basis for consideration. His assumption with regard to the limitation of passenger locomotive and multiple-unit car mileages is entirely correct; the morning and afternoon suburban traffic to and from New York City, with its close headway, makes the problem of securing high car and locomotive mileage most difficult.

Answering Mr. Wynne's question as to the statement of increased reliability of operating when electric was substituted for steam service, I would advise that this was, as he surmised, upon a failure basis. A fair average for steam locomotive operation might be cited as 5000 miles per engine failure, whereas electrical operation certainly should be 12,000, and in a number of instances on the New Haven it has been as high as 18,000, and it is my understanding that both the Pennsylvania Road and the New York Central Road have reached figures higher than this, our own mileage having been lower than the others, due chiefly, I think, to the requirement of the dual A. C.–D. C. operation.

I am entirely in agreement with Mr. Wynne that the maintenance and repairs on electric locomotives should be compared to those of steam upon the basis of equal service and weight on drivers.

Again I find comfort in Mr. Wynne's emphasis of the highest importance to securing the proper electrical administrative forces in the electrified zones of steam railroads.

Answering Mr. Wynne's inquiry with regard to Table No. 17, as explained in my general note forward to this discussion, no allowance was made for depreciation under fixed charges.

Mr. Philip Torchio's contribution is of great interest, and shows the trend and possibilities of large central-station power in the field of electrification. The introduction of an alien power to produce drawbar pull upon a railroad is certainly a departure from past practice. The acceptance of this practice hyphenates the name of the mechanical superintendent, and the central power stations who have relieved him of a part of his duties will do

well to see that this new step is justified, and it can only be justified by a practically perfect continuity of service.

Many railroads electrifying will insist upon the internal control of their entire power, others will mingle purchased power with their own power, and, finally, still others will depend entirely upon purchased power. I see no particular difficulty arising in any one of these three arrangements of supply, and I have agreed with Mr. Torchio that the only true basis for a contract by a railroad for the supply of outside power will be that that power can be supplied with as equal reliability as the power could be produced by the railroad company and at equal cost.

The higher thermal efficiency secured in the use of large generating units affords an opportunity for large central-station plants to sell power to railroads, a measure of the justifiable profit in this sale being in the difference in efficiency between the smaller generating station (required by the railroad) and that of the central station. Such an arrangement as Mr. Torchio has pointed out provides an economical supply of power, and at the same time obviates the necessity of the railroad company investing in this feature required for electrification. Indeed, and digressing for a moment, I will go a step further under Mr. Torchio's thought and say that in these days when railroads are so hard up for cash the " Equipment Trust " offers a relief in the matter of the purchase of electric motive-power equipment, leaving as the only cash investment necessary on the part of the road electrifying that incident to the cost of the distribution and contact system required for the operation of its trains, and such buildings or modifications of buildings as will cover the shopping requirements of the new electrical equipment.

Commenting on Mr. Alfred W. Gibbs's valuable contribution in the discussion: His first point is well taken, and has been long recognized as one of the serious capital and operating expenditures where the problem of electrification is applied to deviating lines entering a city, and unless, as Mr. Gibbs points out, each one of these lines is electrified throughout the entire division, it is necessary to arrange local terminals to permit a change from steam to electrical operation. Such a condition, for example, is manifest in the study of the electrification of the various lines of the New York, New Haven and Hartford, the Boston and Albany, and the Boston and Maine Railroads entering the city of

Boston. As Mr. Gibbs advises, this is quite properly a charge to electrification, and a heavy one. On the other hand, large cities gridironed with their entering roads may have a density upon these tracks which will permit the terminal charges and still be within the economic limit of electrification. The tendency will be, of course, to electrify roads entering the cities upon which the greatest traffic obtains, and those having a lesser density will in turn be electrified as increased density justifies. The difficult financial situations in which the railroads of to-day find themselves are becoming better appreciated daily by the public, and it is safe to assume that, as density of traffic is the controlling factor in electrification, a city's people will see the justice of such a proposed procedure.

I fear my remark with regard to the third rail "having gone to seed" has been given more weight by Mr. Gibbs than was intended. Let me hasten, therefore, to withdraw any seeming attitude of criticism on my part with regard to the engineers responsible for the introduction of the direct-current system, particularly in the New York City terminals. But I confess that the adoption of the overhead system by the Pennsylvania Railroad Company for its Philadelphia electrification offered partial grounds for the suggestion that the third rail was past its flowering stage.

Mr. Gibbs's table showing the economy of steam locomotives with more liberal boiler capacity and with superheat is most interesting. The note that Mr. Gibbs adds, however, that *"These are the rates when running, added to which are certain standby losses at terminals,"* transforms "test" into practical conditions, and, as explained in my commentaries on Mr. Henderson's discussion, the improvement in thermal efficiency of central power stations can easily keep pace with any similar improvements in the steam locomotives. I feel sure that Mr. Gibbs will later find that my statement with regard to this matter is correct, and, if he does so, will take the first opportunity to withdraw his criticisms of my statement that "one pound of coal burned under the boiler of a central power plant will develop twice the drawbar power that the same amount of coal will produce when burned in a locomotive firebox." When I made the statement I had, of course, reference to the average conditions of practical operation.

As explained in the paragraph forward to my commentary

on the general discussion, the figures for depreciation upon the Cos Cob power station were not included, and for comparative purposes they should have been allowed. Mr. Gibbs has named a rate of 0.35 cent or 4 cents per k.w.h. as the amount that should apply, and it is to be noted that upon the basis of eleven per cent. upon the total investment made, covering interest, insurance, depreciation and taxes, the figure 0.29 cent, while less, does not differ greatly from that suggested by Mr. Gibbs.

Mr. Wheeler discusses most interestingly two vitally important points on the matter of electrification:

(1) The form of electric power which may be standardized for all classes of train service.

(2) The inheritance in the electric zone of "steam-trained" operators.

With regard to (1), the question of the location of the rectifier on or off the locomotive will always admit of local analysis for the most economic result. Mr. Wheeler has pointed out some very interesting possibilities in this direction.

With regard to (2), the matter of electrical administration, I have already expressed myself at such length on this matter that it will be only necessary to acknowldge with interest Mr. Wheeler's concordant sentiments.

Mr. W. A. Del Mar has asked some very pertinent and interesting questions, which I am very glad to answer. With regard to the expenditures made to reduce telephone disturbances, and of altering the right of way to conform with electrical requirements, these were included in the general figure of $15,000,000 mentioned in the paper. It is of interest, however, to note that past experience has indicated a proper method of laying out the transmission and distribution system whereby automatic compensation for telegraph and telephone disturbances can be secured for a very nominal amount. For example, in the case of the electrification of the four-track lines between Stamford and New Haven, the arrangement of transmission and distribution for the most economic traction result proves the most efficacious for reduction of the telegraph and telephone disturbances.

It is of interest to note that Mr. Del Mar is appalled at the development charges of the single-phase system, and, while I am at a loss to understand how a "fact" can be presented in an "ingenious way," as an example of a reduction of costs, our

strain insulators in 1907, when we first began the electrification, cost $63. To-day, with factors of safety three times both the electrical and mechanical values they had in their original installation, the cost has been reduced to $7. A longer experience in the handling of work-train service and the administration of construction work upon those work trains are points along the curve representing forty per cent. in the reduction of construction, etc.

With regard to the four questions Mr. Del Mar has asked, I am glad to answer them as follows:

(1) *Q.* Do these mileages include or exclude yard switching?

A. The mileages given for both passenger and freight service do not include yard switching (*yard switching* is taken care of by yard switchers designed especially for that purpose).

I would advise, however, that the locomotive miles as shown on line 2 of the operating statistics, in both the case of the passenger and freight service, include the mileage of locomotives in trains and also the miles "run light" between engine-houses and stations. In figuring the passenger operating costs, however, the mileages of engines "run light" between stations are also included, thus giving the total passenger locomotive miles, and in figuring the operating costs on freight locomotives likewise the miles of light moves and the mileage of locomotives switching at way stations on the main line are also included. It would doubtless be of interest to Mr. Del Mar to know that we have added a third sheet of statistical information having reference only to yard switching mileage and yard switching costs, which sheet had not been inaugurated at the time the paper was written.

(2) *Q.* If they exclude yard switching, do not the operating costs appear unduly high? If they include yard switching, how is it estimated?

A. The above answer to Question 1 doubtless serves as an answer to Mr. Del Mar's second question. While agreeing to his statement that the costs are high, I only hope that I have made the reason for this clear, especially in view of the typical record of the costs of maintaining the ten engines which at the time of the paper had received a full overhaul in the new shops. As previously explained, some of these engines had run 300,000 miles without undergoing any general repairs.

(3) *Q.* Are light locomotive mileages included in train miles?

A. The train miles did not include the mileage of loco-

motives "run light," but have been recorded and are included in the total locomotive mileage in computing the unit cost per locomotive mile both in freight and passenger service.

(4) *Q.* The fixed charges given for Cos Cob power station appear to be very low. It would be interesting to know whether they include depreciation.

A. As explained in the previous part of this discussion, they did not include depreciation.

Mr. Del Mar's point with regard to the negligible error of meter registration on locomotives is very interesting, and, so far as we have been able to determine, the meters have been an accurate and valuable adjunct in the determination of the general distribution of power.

The Fire Hazard in Turbo-Generators. G. S. LAWLER. (*National Fire Protective Association,* vol. 8, No. 4.)—The chances of electrical generators of the older types being seriously injured by fire in the event of some part of the insulation failing are slight. Their freedom from fire damage is due principally to the comparatively low speeds, the accessibility of the combustible insulation, and the large mass of the machines per unit of capacity. In the case of generators of the turbo type this condition is reversed. Undoubtedly manufacturing companies have given the subject serious thought and have employed all means practical at the present time to reduce the fire hazard to a minimum, but there is still very much to be desired. Besides improving the non-combustible properties of the coverings, it would seem feasible to provide means for cutting off the ventilating system and thus diminish the supply of oxygen, or even to introduce carbon dioxide in the place of air in the cooling system.

The Theory of Cold Light. W. D. BANCROFT. (*Transactions of the Illuminating Engineering Society,* vol. x, No. 4.)—It is claimed that all chemical reactions tend to emit light, and that they all emit light if made to take place very rapidly. It is shown that the luminescence of salts flames is a chemiluminescence, and the method of determining the reaction is outlined for the specific case of cupric chloride. If a suitable chemical reaction can be made to take place sufficiently rapidly without any marked evolution of heat, cold light is obtained. The firefly has solved this problem, though the nature of the substance which oxidizes is not known. The chemist will some day solve it in another way. The Moore light is probably a case of chemiluminescence, but most commercial forms of lighting depend on temperature radiation for their efficiency.

The Estimation of High Temperatures by the Method of Color Identity. C. C. PATERSON and B. P. DUDDING. (*Proceedings of the Physical Society of London,* vol. xxvii, part iii.)—(1) Preliminary experiments are described on the method of "color identity" adapted to the estimation of the temperature of incandescent substances, such as metal or carbon radiating in the open; by this method the "true" temperature of certain bodies as distinct from their "black body" temperatures can be arrived at with a very fair degree of accuracy. (2) By the color identity method the total luminous radiation (white light) from a black body is made identical in color with that from the incandescent metal under examination by adjusting the black body until there is color identity in the field of a Lummer-Brodhun photometer. (3) Comparisons are made with the results so obtained with those obtained by other methods, and the color identity method is shown to give the correct result for melting platinum. (4) Formulas are deduced, based on the fundamental theories of energy radiation and the sensitivity of the eye, connecting the temperature of carbon and tungsten filaments with their lumens per watt, and it is shown that these expressions hold from the lowest to the highest values of lumens per watt. (5) It is shown that the color identity method of determining filament temperatures is practically independent of the cooling at the ends of the filaments of ordinary lamps. (6) An explanation is given of the principal factors and limitations of the color identity method, in which it is shown that accurate results should be obtained so long as the bodies under consideration act as "gray" bodies throughout the visible spectrum, and that there will be a tendency to error to the extent that they depart from the gray body condition in the *visible spectrum.* (7) The color of the radiation from melting platinum is shown to be the same as that from a carbon filament lamp operating at 2.65 lumens per watt or 4.75 watts per mean spherical candle or, approximately, 3.8 watts per mean horizontal candle.

Largest Commercial Gasoline Engine Ever Built. ANON. (*Scientific American,* vol. cxii, No. 24, 588.)—What is said to be the largest gasoline engine ever built has been installed in a double-ended ferryboat utilized for the transportation of trains across an arm of San Francisco Bay. Although designed for marine work, it shows to a remarkable degree the influence of automobile practice in its general appearance. Weighing approximately 120,000 pounds, this 600-horse-power unit is the climax of a gradual development of the heavy gasoline engine on the Pacific coast. It has four cylinders of 16-inch bore, each measuring nearly six feet and weighing 1700 pounds. The normal speed of the engine is 225 revolutions per minute. The trips are not long, and between runs all fuel consumption ceases, effecting a considerable saving over steam despite the high cost of fuel for operating an engine of this size.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF THE QUALITY OF PLATINUM WARE.†

By George K. Burgess and P. D. Sale.

[ABSTRACT.]

THERE has been devised a simple, thermo-electric method suitable for the determination of the purity of platinum ware. This method does not mar the article tested, and gives data for the classification of platinum in terms of its equivalent iridium (or rhodium) content.

There were examined by the thermo-electric method 164 pieces of platinum ware, of which 26 per cent. contained less than 0.5 per cent. iridium and 67 per cent. less than 2 per cent. of iridium. Of 84 crucibles, 36 per cent. contained less than 0.5 per cent. iridium and 87 per cent. less than 2 per cent. iridium.

A method has been developed for determination of the exact loss on heating of platinum crucibles by means of a suitable electric furnace containing no heated metal parts.

Fourteen crucibles of various makes and grades were examined for loss in weight on heating and after acid treatment following each heating. Their magnetic susceptibilities were also determined. The susceptibility of pure platinum is zero, and the range of susceptibility of seven crucibles is 1 to 125.

The heating losses per 100 cm.^{2} of practically iron-free crucible surface at 1200° C. ranged from 0.71 mg. to 2.69 mg. per hour, the lesser losses being for crucibles containing rhodium and the greater losses being associated with iridium.

Iron appears to lessen somewhat the loss of weight on heating, but its presence is objectionable on account of the soluble oxide formed on the crucible surface. The chemical analysis and magnetic measurements place the crucibles in only approximately the same order as to iron content; the magnetic susceptibility is not, however, proportional to the iron content.

* Communicated by the Bureau.

† To appear as a Scientific Paper of the Bureau of Standards.

It appears to be possible, from thermo-electric and microscopic examinations of a crucible, to predict its probable loss of weight on heating within limits close enough for analytical purposes.

Suggestions are offered concerning the specifications of highest grade platinum crucibles, including the substitution of rhodium to 5 per cent. for iridium, and the practical elimination of iron.

Whether crucibles have been long in use or not, after the first two or three heatings and acid washings, appears to make little or no difference on their behavior as to losses on heating and washing.

The nature of the process of disintegration of platinum and its alloys is briefly discussed.

A DIRECT-READING DEVICE FOR USE IN COMPUTING CHARACTERISTICS OF VACUUM TUNGSTEN LAMPS.

By J. F. Skogland.

[ABSTRACT.]

IT has been shown in a previous paper * that the ordinary characteristic relations of vacuum tungsten lamps may be expressed with high precision by a set of characteristic equations, each involving two variables; or solutions may be made more quickly by employing tables computed from the equations. For example, having given observed values of voltage, candle-power, and watts per candle, the values of candle-power and watts per candle at any other voltage are obtained from the equations or tables as follows:

1. From the observed values of voltage and candle-power their normal values,—that is, their values at normal watts per candle (1.20),—are computed.

2. The ratio of the desired voltage to the normal voltage just found is computed.

3. Substitution of this voltage ratio in the proper equations, or reference to the corresponding point in the tables, gives a candle-power factor and the actual watts per candle.

* Middlekauff and Skogland, "Characteristic Equations of Tungsten Filament Lamps and Their Application in Heterochromatic Photometry," Bulletin of the Bureau 11, p. 483 (1914); Scientific Paper No. 238.

4. The normal candle-power is multiplied by the candle-power factor to obtain the desired candle-power.

This process, though simple, requires considerable time before a solution is obtained. The direct reading device here described and presented ready for use solves directly and without preliminary reduction all problems introducing as variables the voltage, candle-power, and watts per candle of vacuum tungsten lamps. Its construction depends directly upon the characteristic equations mentioned above.

This device consists of volt, watts per candle, and per cent. candle-power scales. The watts per candle and per cent. candle-power scales are fixed in their relation to each other. The volt scale is arranged to be detached from the plate, so that it may be applied to the fixed scales at the point corresponding to observed values of watts per candle and voltage.

From a single setting of the volt scale to observed values within the range of from 0.70 to 2.05 watts per candle may be read values of any one of the variables at any other point within this range. The volt scale has a range of from 94 to 166 volts. The chosen limits of watts per candle and voltage are considered sufficient to include settings and solutions for 105- to 130-volt lamps in standardizing and life test-work.

A test of the device, illustrated in part by examples, indicates that, on an average, values of per cent. candle-power and of watts per candle read therefrom deviate from those obtained by use of Tables 20 and 22 of the paper just referred to by amounts not exceeding 0.10 per cent. and 0.05 per cent. respectively; also that values read from the scales check observed values very nearly as closely as those computed by use of the tables.

All of the points (referred to horizontal and vertical scales of equal parts) through which lines of the scales of this device were drawn have been tabulated, so that similar scales of the same or different range may be constructed directly from these values. Sufficient discussion of the derivation of these values and of the relative position of the scales has been given to direct the construction of scales not included within the watts per candle range here employed. By the general method of this paper any related functions of exponential form and of the same degree as the characteristic equations may be represented and used as scales of a similar device.

The chief merits of the device when compared with other methods of characteristic evaluation seem to be its simplicity, precision, and saving of time resulting from its use. Solutions are made directly, without reference to normal watts per candle, voltage ratios, exponents, etc. These considerations should recommend it to testing and standardizing laboratories.

CONSTRUCTION OF PRIMARY MERCURIAL RESISTANCE STANDARDS.

By F. A. Wolff, M. P. Shoemaker, and C. A. Briggs.

[ABSTRACT.]

THE paper deals with the construction of four one-ohm mercury standards of resistance in accordance with specifications adopted by the International Conference on Electrical Units and Standards (London, 1908).

The London Conference defined the international ohm as the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grammes in mass, of a constant cross-sectional area and of a length of 106.300 centimetres.

Owing to the impossibility of exact realization of the above conditions, principally because of the impracticability of securing glass tubing of strictly uniform bore, certain specifications were essential. Those adopted specified that the tubes used must be made of a glass the dimensions of which change little with time; that they be well annealed and straight; that the bore be as nearly as possible uniform and circular; that the area of cross-section of the bore be approximately one square millimetre, and that the mercury have a resistance of approximately one ohm.

It was also specified that each tube be accurately calibrated, and that no tube have a calibre correction greater than 5 parts in 10,000. The length of the tube, the mass of mercury the tube contains, and the electrical resistance of the mercury must all be determined at a temperature as near to 0° C. as possible, all measurements being corrected to 0° C.

The four tubes used at the Bureau were selected from a large number of tubes of Jena 59 III glass, specially drawn by Schott

and Genossan, and were straightened, annealed, and graduated by M. Dandin in Paris.

At the Bureau of Standards they were very carefully calibrated, their calibre factors, ranging from 1.000047 to 1.000096, being determined to an accuracy of about one part in a million.

The tubes were cut at points giving a resistance, including the end correction, of approximately one ohm, the cuts being located at points for which the cross-section could be most accurately calculated. The ends were ground and plane polished. The tubes were tapered at the ends to fit into the end bulbs, used in making electrical measurements, and the glass cleaning and drying fittings.

The Reichsanstalt method was employed for the determination of Mo, the mass of mercury required to just fill a tube at 0° C. A tube was exhausted, filled with mercury and placed vertically within a double-walled ice-bath, the lower end of the tube being sealed by a plane polished plate and the upper end, carrying a slight excess of mercury, being protected by a ground glass cap.

The excess of mercury was removed by stroking off with a plane polished glass plate in a gimbal mounting, the condensation of moisture being eliminated by a current of cooled and dried air directed at the end of the tube and at the stroking-off plate. Weighings were made in a special balance room, on a Stückrath balance sensitive to a hundredth of a milligramme. Six fillings of each tube were made, the mean of the average deviations of the individual fillings from their respective means being but ± 4 parts per million.

The problem of determining L_o, the length of the axis of a tube at 0° C., was reduced, through the use of suitably-ruled end pieces of platinum-iridium, from one of comparing end standards to that of comparing line standards. Comparisons were made directly with corresponding known intervals on a nickel-steel meter. The length constant added, due to the end pieces, was determined by abutting the end clips and measuring the interval between the lines on them by comparison with a subdivided decimetre standard. The probable error in the lengths as determined, all things considered, did not exceed five ten-thousandths of a millimetre.

Electrical comparisons of the mercury units were made by the Thomson bridge method, the mercury units and five sealed

manganin standards being substituted in turn in the same bridge arm.

The ratio coils and the manganin standards were contained in a thermostatically controlled oil-bath, while the mercury units were in the ice-bath adjoining. Connections from the tubes to the bridge were made by inserting heavy copper conductors in the glass terminal protecting tubes of the end bulbs employed, the tubes being partly filled with mercury.

Seven fillings of each tube for electrical comparison were made in 1911. The international ohm as defined by the four mercury standards was found to be 25.5 millionth smaller than the international ohm as represented by the manganin coils at that time. The average deviation of the four tubes from their mean was but ± 5 parts per million.

A second and third series of electrical comparisons, made in June and December, 1912, showed the mercury standards to have changed with respect to the wire standards. Redeterminations of Mo, L_o, and the calculated R_o were therefore made for each tube, the average change found being 1.1, 9.4, and 8.2 parts per million respectively.

On the basis of the above new determinations the international ohm, as represented by the four mercury standards in December, 1912, was 12.5 millionths smaller than the international ohm as represented by the manganin coils at the same time.

England, Germany, Japan, Russia, France, and the United States now have mercury standards of resistance. Comparison of the units defined by the mercury standards of the above countries in 1913 (those of France excepted, dates not being available) indicate a very satisfactory agreement, the average deviation of the units of the several countries from the mean being about ± 7 parts per million.

THE FRANKLIN INSTITUTE

AWARD OF THE FRANKLIN MEDAL.

At a stated meeting of the Institute, held on the evening of Wednesday, May 19, 1915, Dr. Walton Clark, President of the Institute, presiding, the Institute's Franklin Medal was awarded to:

HEIKE KAMERLINGH ONNES, of Leiden, Holland, in recognition of his "long-continued and indefatigable labors in low-temperature research, which have enriched physical science not only with a great number of new methods and ingenious devices, but also with achievements and discoveries of the first magnitude."

THOMAS ALVA EDISON, of Orange, N. J., in recognition of the value of "numerous basic inventions and discoveries forming the foundation of world-wide industries, signally contributing to the well-being, comfort, and pleasure of the human race."

The work of Professor Onnes and Mr. Edison was described by Dr. Harry F. Keller, and Dr. George A. Hoadley followed by a statement relating to the founding of the Franklin Medal.

At the conclusion of the regular business of the meeting the president of the Institute, Dr. Walton Clark, said:

The Chair now recognizes Dr. Keller to introduce the medallists upon whom, on the recommendation of the Committee on Science and the Arts, have been conferred the Franklin Medal, generously founded by Mr. Samuel Insull and nobly designed by Dr. R. Tait McKenzie.

Dr. Keller: Mr. President, our gathering here to-night in this venerable hall is an occasion of peculiar gratification and of rejoicing to the members of The Franklin Institute. It is not the recurrence of a time-honored custom, but an event which is to initiate a new series of annual functions of this Institute, made possible by the munificence of one of its distinguished members.

Your presentation, Mr. President, of the two first impressions of the Franklin Medal marks the inauguration of what we hope will every year stand out as a red-letter day in our calendar, the crowning of supreme achievement in science by the award of a medal of such artistic merit and intrinsic value as to render it a fitting tribute to the recipient.

The donor of the fund which enables The Franklin Institute to confer such an award upon scientific discoverers and inventors is Mr. Samuel Insull. He is the president of a corporation which owes its inception and its marvellous success in a large measure to scientific labor and inventive genius, to discoveries and their practical applications which have been made, not by one man, or a few men of our country, only, but by a host of workers whose lives and activities had their scene in every part of the civilized world. With these facts in mind, Mr. Insull has wisely and fittingly defined as the scope of

the new award the recognition of highest achievements in the fields of pure and applied science, without regard to the nationality of the scientist.

As in the case of the other awards made by the Institute, the naming of the Franklin Medallists has been entrusted to the Committee on Science and the Arts, and, in accordance with its custom, this committee has delegated that responsible and pleasant duty to a sub-committee of which I have had the honor to be chairman.

Impressed with the importance of recommending for the initial awards names that might stand as precedents for the coming years, the sub-committee decided upon a course which, it is hoped, will meet with the approbation of both the Institute and the public. In order to emphasize the broad scope as well as the international character of the award, it was agreed that of the two names chosen one should be that of a scientific investigator and the other a representative of applied science; also that one of the medallists should be an American and the other a foreigner. In view of conditions resulting from the war which is raging in Europe, it was deemed advisable that, other things being equal, the foreign medallist should be a citizen of a neutral country.

The two names which were the unanimous choice of the sub-committee, and which had also the unanimous approval of the Committee on Science and the Arts, meet these conditions in every respect. It may be doubted whether the selection would have been different even if it had been made without any restrictions.

The question as to which of the two awards should go to the American and which to the foreigner did not seem difficult to decide, for, while it is true that our country is now contributing its full share, and even more than that, to the advancement of science, it is universally conceded that in the practical application of scientific principles the American people are preëminent. If our country can claim to be "the land of unlimited possibilities," this phrase may certainly be applied also to the inventive power and the engineering skill of her sons. It was natural, therefore, to think of an American in connection with the award in applied science.

The scientist we desire to honor for the truly wonderful achievements he has made in experimental physics is a native of Holland, and professor in the University of Leiden. Heike Kamerlingh Onnes was little known, even among men of science, until a few years ago, when he announced the liquefaction of helium at a temperature but a few degrees above absolute zero. The award of the Nobel Prize for Physics in 1913 first directed popular attention and curiosity to the work of this scientist, and to that unique workshop of his in the Leiden University, the cryogenic laboratory. Attention was then called to the fact that the production of extreme low temperatures and the liquefaction of helium by Professor Onnes were by no means the fruits of what might be called *tour de force,* but the culmination of long-continued, comprehensive researches, involving profound knowledge, inventive power, experimental skill, and ability of a high order to organize and direct. This work in molecular thermodynamics derived its inspiration from van der Waals's epoch-making investigations on the critical states, and practically began in the year 1882, when the two most distinguished physicists which Holland has

produced, H. A. Lorentz and H. Kamerlingh Onnes, were appointed to the chairs in physics in the University of Leiden.

The coöperation of the two men soon made Leiden a centre of physical research. As is well known, the achievements of Lorentz lie mainly in theoretical and mathematical physics, but Onnes at first directed his attention to the equipment and development of the laboratory. *"Door meten tot weten"* ("knowledge rests upon measurements") he inscribed above its entrance. His great ambition was the creation of a laboratory devoted to low-temperature research. To attain this object he abandoned for many years the researches on which he had been engaged, and devoted his time to the construction of apparatus for the liquefaction of gases and the measurement of low temperatures. As a part of his plan he attached to the laboratory a training school for instrument makers, in which instruction was also given in the handling of apparatus. It was thus that he secured the staff of trained assistants which he required for his experimental work.

During the ten years he spent on constructing the cryogenic laboratory he also directed numerous important researches on electro-optical and magneto-optical subjects. In this work he enjoyed the constant coöperation of Professor Lorentz, who doubtless suggested many of the problems. Among the results was the great discovery known as the Zeeman effect.

After the completion of the liquid-oxygen equipment of his laboratory, Onnes decided to devote his entire time and attention to low-temperature research. Since 1900 the *Leiden Communications*, the official publication of the laboratory, presents a record of the rich harvest of results and discoveries he secured in the cryogenic laboratory. He attempted the liquefaction of hydrogen, but in this and in the solidification of hydrogen Professor Dewar, of London, his great rival, stole a march on him. Onnes, however, immediately took advantage of the new range of low temperatures by extending his equipment so as to permit the investigation of phenomena to temperatures as low as −259° C. In experimenting with a mixture of hydrogen and helium he made the remarkable observation that at the temperature of liquid hydrogen helium can be so compressed that the gas actually sinks to the bottom of the liquid.

After innumerable preliminary trials he finally succeeded, on July 10, 1908, in liquefying helium, an achievement which is one of the greatest triumphs of experimental skill and of ingenious combination of every conceivable resource. The temperature at which liquefaction took place was −269°, and by allowing the liquid to boil under reduced pressure a temperature but one degree above absolute zero was reached. Time does not permit me to dwell on the great number of new and important results that have been obtained by Onnes himself, as well as by other physicists working in his laboratory, with the aid of liquid helium. In conclusion I would only mention an almost incredible, yet fully substantiated, observation of Professor Onnes; namely, the fact that at temperatures but a few degrees above absolute zero the resistance of metals such as mercury, lead, and tin falls to practically *nil*, so that an electric current will continue to flow almost undiminished after the magnet that has induced the current has been removed from the coil.

Mr. President, I now have the honor to present to you His Excellency,

Chevalier W. L. F. C. van Rappard, who on behalf of the Royal Netherlands Government will accept from you the Franklin Medal for Professor Onnes.

PRESIDENT CLARK: Your Excellency, The Franklin Institute, acting under a recommendation of its Committee on Science and the Arts, has awarded its highest honor—the Franklin Medal and Diploma—to your distinguished countryman, Professor Onnes, for his signal services to humanity, rendered in the field of science.

Pursuant to your kind consent I now have the privilege of presenting this Medal and Diploma to you, to be transmitted to Professor Onnes, through the State Department of your gracious Sovereign. The Franklin Institute is appreciative of the distinction conferred upon it by the participation of Her Majesty's Government in this ceremony.

CHEVALIER VAN RAPPARD (On behalf of the Royal Netherlands Government, for Prof. Heike Kamerlingh Onnes): Mr. President of The Franklin Institute of the State of Pennsylvania and Members of The Franklin Institute: I consider it a great honor and a most agreeable duty to accept at your hands the Franklin Medal, founded by Mr. Samuel Insull, for the recognition of those workers in physical science, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance the knowledge of physical science and its applications. I feel sure that that most distinguished countryman of mine whom you have honored so highly by awarding him the Franklin Medal, if he could be here to-night, to receive himself this high token of your recognition of his abilities and of his labors, would be able to express more eloquently than I am able to do his deep gratitude for the great honor that has been bestowed upon him, and, moreover, he would have found words to express his admiration of your Franklin Institute, and of its influence in the realms of mechanical science and the arts. Therefore, I feel that in this gathering of learned men I am a poor substitute for a man such as Professor Onnes. However, it is perhaps an advantage that he is not here, but that the official representative of the Netherlands now stands before you to receive this great honor that has been bestowed upon one of the Netherlands' most illustrious citizens, because that citizen, illustrious as he may be, is also a modest man, and if he had been here, he probably would have spoken to you only of his personal feeling of gratitude and thankfulness of what you think of him and of your high opinion of his knowledge, but I can do more, I can say that it is not only Professor Onnes who has been honored and is thankful for the great honor that has been given to him, but that also my whole country feels very honored and happy on account of the rare distinction that has been visited on one of its sons. We are proud of Professor Onnes, we know that he is one of the famous men that the old University of Leiden has given not only to Holland, but also to the whole world. It is useless to cite names, you all know them as well as I do. You know that among the famous men Professor Onnes takes a most prominent place, but from to-day we will think more of him and we will rank him higher because that modest worker at the other side of the water has been able to attract upon himself the attention of The Franklin Institute of the State of Pennsylvania.

You know I am a layman. I had heard of the scope of The Franklin

Institute—and every civilized man may feel interested in an Institute bearing the name of Benjamin Franklin—but, Mr. President, you were kind enough to send me some literature and information relating to the Institute and its activities, which documents I have read with the keenest interest, and the more I read, the more I realized how proud Professor Onnes and the Netherlands must be when the Franklin Medal reaches our shores. It will always be a valuable gem fixed to the scientific crown of our oldest university, the University of Leiden, and it will always be a proof that the Netherlands strives to be great in those things in which also a small country can be great. It is therefore my very agreeable task to accept this medal. And let me say that Holland has always considered the United States of America as its big younger brother. The old Dutch settlers came over to your country many years ago, and brought to you those principles of freedom of thought, of tolerance and appreciation of each other's opinions, which have prompted you to award to one of Holland's most prominent citizens this medal, and this action of yours will and must, I feel sure, render the relationship between the two nations still more affectionate, and lead us to feel still more the esteem and friendship we have for each other.

PRESIDENT CLARK: The Chair will again recognize Dr. Keller for a statement of the work of Mr. Edison and the introduction of Mr. Edison for the receipt of the Franklin Medal and Diploma.

DR. KELLER: Mr. President, in some respects the life and labors of the man who is present in person to receive from you the medal awarded him bear a resemblance to those of Professor Onnes, for, like the latter, he is an experimenter with a clear vision of the aims for which he strives, is endowed with an infinite capacity for taking pains, and with a truly marvellous perseverance in carrying everything he undertakes to a successful conclusion. But in other respects the stories of the life-work of the two medallists are widely different. While the activities of Onnes, as I have pointed out, have been directed almost exclusively toward augmenting our knowledge in a well-defined province of physical science, those of the second medallist extend over an almost inconceivable range of subjects from which his keen intellect and magic touch have wrested results that have ministered to the well-being, comfort, and pleasure of mankind.

Almost from the beginning of his career as an inventor his work attracted widespread interest, and I may say without fear of contradiction that no other inventor's name, either in this or any other country, has become so universally popular as his. His inventions and other achievements are so many that even their mere enumeration here would take up far more time than is allotted to me. In view, however, of the fact that the products of his genius have impressed themselves on the popular mind, and that an excellent and sympathetic narrative of his life has been written, it may suffice to briefly refer to the main achievements which the Institute desires to recognize by its highest award.

At the Centennial Exhibition, held in this city in 1876, some electrical inventions were among the objects that aroused the greatest interest, and it was during the decades that followed this event that we witnessed the great burst of activity in the electrical art to which we owe the creation of those vast indus-

tries which characterize our time as the Age of Electricity. In the galaxy of the great names that will ever be associated with this development not a few of the luminaries of the first magnitude were American inventors, and the one that seems to stand out brightest among them all, both as regards the number and value of his achievements, is our medallist.

He began his career as a train boy on a railroad and then became a telegraph operator. As a mere youth he made a number of inventions in connection with telegraphy, among which a stock-ticker became a great commercial success. During the following years we find our inventor engaged upon the development of the automatic telegraph and of duplex and quadruplex telegraphy, and then, after the Centennial year, he turned his attention to the solution of other electrical problems, rapidly forging his way to the front of the pioneers of that time. The enormous difficulties these men encountered in the solution of electrical problems can scarcely be appreciated by the electrical engineer of the present day.

After the invention of the telephone by Alexander Graham Bell it soon became apparent that something more powerful than the magneto transmitter was necessary, among other things, for its commercial success. This was supplied by our medallist when he invented the carbon transmitter, now in almost universal use. It is well known that it is to him also that we owe the invention of countless devices and methods in the art of telephony which have proved of the greatest value in the wonderful development of this industry.

In 1878 he invented the tinfoil phonograph, of which he constructed a number for exhibition purposes. This machine excited a great popular interest, but was succeeded by the wax cylinder machine which he later developed into one of the most perfect phonographs now on the market.

Among his greatest achievements, however, are the contributions he made to the art of electric lighting. He was indeed *facile princeps* among the creators of this industry. After moving to Menlo Park, N. J., in 1876, he was engaged there during a period of ten years on the development of his incandescent electric lamp dynamo, and system of low-pressure electrical distribution. On September 4, 1882, he started the Pearl Street Station in New York City, the first successful electrical station in America, an achievement which will ever remain a monument to his ingenuity, skill, and tireless energy.

It was followed by the construction of many similar plants both here and abroad.

I can only refer here in passing, as proofs of his marvellous resourcefulness and versatility, to his pioneer work on electric railways, his invention of the motion-picture apparatus, and his successful work on alkaline storage batteries, magnetic ore milling, the manufacture of Portland cement, and reënforced concrete construction. That he has lost none of his youthful energy and determination is evidenced in the rapidity with which he has reconstructed the enormous factories at Orange, N. J., destroyed only last December by a disastrous fire.

Writing in 1910, his biographers made an estimate of the extent of those industries which are either founded upon or affected by his inventions. They sum it up by saying that his work "has been one of the most potent factors

in bringing into existence new industries now capitalized at nearly $7,000,000,000, earning annually over $1,000,000,000, and giving employment to an army of more than six hundred thousand people." These figures represent only the industries in this country, and are probably far below the actual values and numbers of to-day.

The wizard who has made these stupendous achievements is, of course, none other, Mr. President, than the peerless inventor known to all the world as Thomas Alva Edison, whom I now have the honor of presenting to you.

PRESIDENT CLARK: Mr. Edison, I have the honor, in the name of The Franklin Institute, upon the recommendation of its Committee on Science and the Arts, and in recognition of your distinguished services to humanity rendered in the field of science, to present to you the Franklin Medal and Diploma—the highest honor in the gift of the Institute.

PRESIDENT CLARK: The Chair will now recognize Dr. Hoadley, who will make a statement in connection with the founding of the Franklin Medal Fund.

DR. HOADLEY: Mr. President, one of the important functions of The Franklin Institute is that of awarding the various medals and premiums of which it is the custodian.

These awards form a notable list, including the Certificate of Merit, the Longstreth Medal, the John Scott Legacy Medal and Premium, the Potts Medal and the Elliott Cresson Gold Medal, the winning of any one of which is a mark of recognized merit.

All of these awards, however, are for some specific device, invention, or application of scientific principles.

The particular award that has hitherto not been available, and the lack of which has been seriously felt by the Institute, is one through the bestowal of which a man's life-work could be recognized and his achievements crowned.

It has been the fortunate experience of The Franklin Institute that the character of its work is so well recognized that whenever its needs have become known some friend has come forward to supply the deficiency.

The proverbial good fortune of the Institute did not desert it on this occasion, for Mr. Samuel Insull, President of the Commonwealth Edison Company of Chicago, a lifelong friend of Thomas A. Edison, and for many years his valued assistant, undertook to provide a fund sufficient to maintain a medal suitable for the desired purpose.

The character of this purpose is outlined in a statement in the deed of trust, indicating that the medal is to be called the Franklin Medal, that it is to contain a medallion of Benjamin Franklin, taken from his portrait by Thomas Sully, which is in the possession of The Franklin Institute, and that the award is to be made "to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of The Franklin Institute, have done most to advance physical science or its applications."

It is indeed fortunate that on this evening, when the first presentation of the Franklin Medal is made, its founder should be with us.

It has seemed fitting that on this occasion the appreciation of the Institute should be expressed by a testimonial to the donor, therefore, Mr. President,

I have the honor to present to you Mr. Samuel Insull, the founder of the Franklin Medal.

PRESIDENT CLARK: Mr. Insull, I am commissioned by The Franklin Institute to formally thank you, in its name, for your contribution toward that encouragement of the mechanic arts which it is the function of the Institute to promote. Through your generosity the Institute is enabled, as never before, to express its appreciation of a life of eminent service in science.

As an evidence of our appreciation of the service you have thus rendered toward the promotion of the mechanic arts, the Institute asks you to accept this artist's proof of the medal founded by you, and bearing the immortal name of "Franklin."

Before delivering the address of the evening, "Electricity and Modern Industrial Growth," Mr. Insull expressed Mr. Edison's appreciation of the honor conferred upon him in awarding to him the Franklin Medal for his inventions and discoveries, and of his own appreciation of the privilege he felt had been his in contributing to the Institute's means of recognizing the work of great scientists and inventors.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 2, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 2, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for first reading:

No. 2628.—John Underwood and Company's Combined Typewriting and Calculating Machine.

No. 2636.—Lenker's L-E-Vation Rod.

No. 2643.—Street Locomotive Stoker.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 9, 1915.)

RESIDENT

DR. ENOCH KARRER, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pa.

MR. E. F. KINGSBURY, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pa.

NON-RESIDENT

MR. H. A. TOULMIN, JR., Schwind Building, Dayton, Ohio.

CHANGES OF ADDRESS.

MR. CHARLES A. BRINLEY, The American Pulley Company, 4200 Wissahickon Avenue, Philadelphia, Penna.

MR. CLARENCE R. CLAGHORN, President, Durham Colliery Company, Durham, Washington.

MR. PARKE D. MASSEY, Pasto, Colombia, South America.

MR. GEORGE A. ORROK, Lee, Mass.

PROF. I. M. RAPP, Phœnixville, R. F. D. No. 2, Penna.

MR. W. S. RUGG, care of Crescent Athletic Club, Shore Road, Brooklyn, N. Y.

MR. W. F. THORNTON, Mechanicsburg, R. R. No. 2, Cumberland County, Penna.

NECROLOGY.

Colonel Caldwell K. Biddle was born at Rio de Janeiro, Brazil, in 1862, and died in Philadelphia on June 2, 1915.

His early education was secured in private schools in Philadelphia. Later he entered St. Paul's School, Concord, N. H., and in 1884 graduated from the Academic Department of the University of Pennsylvania, and in 1886 from the Law School. Soon after this he was admitted to the bar and began the practice of law.

Colonel Biddle took a great interest in military affairs, and for a number of years was a member of the First Troop, Philadelphia City Cavalry. Later he became connected with the Third Regiment, National Guard of Pennsylvania, as second lieutenant of Company H, and during the Spanish War served in Cuba as Captain of the company. In 1900 he was appointed Regimental Inspector of Rifle Practice, in 1901 he became Second Major, and in 1911 he was elected Colonel of the Regiment.

Colonel Biddle was a member of the University Club and other organizations.

He became a life member of The Franklin Institute in 1900.

Lewis Metzler Clement was born at Niagara, Ontario, Canada, August 12, 1837, and died at Hayward, Cal., October 29, 1914.

He was employed in the construction of the Montreal Water Works and was engineer in charge of construction of the Welland Railway. He was also engaged in the construction of the Port Dover and Hamilton Railway, and later was employed by the Ohio and Mississippi Railroad.

In the spring of 1862 he was engaged by the Central Pacific Railroad as assistant chief engineer. At this time the railroad was being built from Sacramento to Ogden, Utah, and Mr. Clement was in charge of the construction of the line over the Sierra Nevada Mountains. He put in operation the first electric patrol system for railroads, which covered a distance of fifty miles, through snow sheds and tunnels.

He designed the first emigrant sleeping car used by the railroads of to-day, and introduced many notable improvements in the design and construction of steam, cable, and electric railways.

Mr. Clement was appointed chief engineer of the Atlantic and Pacific

Railroad in 1881, and afterwards chief engineer of the Pacific Improvement Company of California, in the construction of cable and electric railways. He was also consulting engineer of the Southern Pacific Company and the Leland Stanford, Jr., University.

Mr. Clement was elected a member of The Franklin Institute in 1899.

Stuart Wood, 1620 Locust Street, Philadelphia.

LIBRARY NOTES.

PURCHASES.

BENOIT, J. R., AND GUILLAUME, C. E.—La mesure rapide des bases geodesiques. 1908.

COX, JOHN.—Beyond the Atom. 1913.

ELLIOTT, CHARLES E.—Engineering for Land Drainage. 1913.

MARSHALL, ARTHUR.—Explosives, Their Manufacture, Properties, Tests, and History, 1915.

MILLS, W. T.—American School Building Standards. 1915.

MORSE, WILLIAM F.—Collection and Disposal of Municipal Waste. 1908.

MYERS, D. F.—Preventing Losses in Factory Power Plants. 1915.

National Association of Cement Users.—Proceedings, vol. 8. 1912.

PHILIP, JAMES C.—Physical Chemistry; its Bearing on Biology and Medicine. 1913.

RIDEAL, SAMUEL AND E. K.—Water Supplies: Their Purification, Filtration, and Sterilization. 1915.

STECHER, G. E.—Cork: its Origin and Industrial Uses. 1914.

THOMPSON, S. P.—Rose of the Winds: Origin and Development of the Compass Card. 1913.

TOMKINS, ERNEST.—Science of Knitting. 1914.

WEIMARN, P. P. VON.—Zür lehre von den Zuständen der Materie. 2 volumes. 1914.

West Virginia Geological Survey.—Logan and Mingo Counties—Report and Maps. 2 volumes. 1914.

WILEY, H. W.—Principles and Practice of Agricultural Analysis. Part 2, Fertilizers and Insecticides. 1908.

GIFTS.

Beghin, A., Regle a Calculus, Modele Special. Paris, 1899. (From Mr. L. E. Picolet.)

Boston Transit Commission, Twentieth Annual Report. Boston, Mass., 1914. (From the Commission.)

British Journal Photographic Almanac and Photographer's Daily Companion. London, 1915. (From Mr. L. E. Picolet.)

Canada Department of Mines, Memoir 30, The Basins of Nelson and Churchill Rivers, 1913; Memoir 38, North American Cordillera, part i, 1912; Memoir 56, Geology of Franklin Mining Camp, British Columbia; Memoir 59, Coal Fields and Coal Resources of Canada. Ottawa, 1915. (From the Department.)

Canada Department of Trade and Commerce, Monthly Report, February. Ottawa, 1915. (From the Department.)

Canadian Society of Civil Engineers, Transactions, vol. xxviii, part ii, 1914. Montreal, 1915. (From the Society.)

Catholic University of America, Year-Book. Washington, D. C., 1915. (From the University.)

College of William and Mary, Catalogue, 1914–1915. Williamsburg, Va., no date. (From the College.)

Cullman Wheel Company, Catalogue No. 10 of Sprockets. Chicago, Ill., no date. (From the Company.)

Dodge Sales and Engineering Company, Catalogue of Gears. Mishawaka, Ind., no date. (From the Company.)

Dominion Bridge Company, Ltd., Catalogue S-1 of Bridges and Steel Structures. Montreal, Can., 1915. (From the Company.)

Duplex Hanger Company, Inc., Catalogue of Hangers. Cleveland, Ohio, no date. (From the Company.)

Eynon-Evans Manufacturing Company, Catalogue No. 10 of Hydraulic and Special Machinery. Philadelphia, no date. (From the Company.)

General Fireproofing Company, The Fireproofing Hand Book. Youngstown, Ohio, 1915. (From the Company.)

Georgia Geological Survey, Bulletin No. 30, A Preliminary Report on the Feldspar and Mica Deposits of Georgia. Atlanta, 1915. (From the Survey.)

Golden-Anderson Valve Specialty Company, Catalogue No. 18 of Steam and Water Specialties. Pittsburgh, Pa., 1915. (From the Company.)

Illinois State Geological Survey, Bulletin of Illinois Coal Mining Investigations. Urbana, 1915. (From the Survey.)

Institution of Engineers and Shipbuilders in Scotland, Transactions, vol. lvii. Glasgow, 1914. (From the Institution.)

Instituto y Observatorio de Marina de San Fernando, Almanaque Nautico, 1916. San Fernando, Spain, 1914. (From the Instituto.)

Jablonski, E., Cours D'Arithmetique. Paris, 1888. (From Mr. L. E. Picolet.)

Keeler, E. Company, Catalogues of Return Tubular Boilers and Water Tube Boilers. Williamsport, Pa., no date. (From the Company.)

Link-Belt Company, Data Book No. 125. Chicago, Ill., 1915. (From the Company.)

Liverpool Engineering Society, Transactions, vol. xxxv. Liverpool, England, 1914. (From the Society.)

Locke Regulator Company, Catalogue N of Regulating Devices. Salem, Mass., no date. (From the Company.)

Louisiana State University, Catalogue. Baton Rogue, 1915. (From the University.)

Manchester Steam Users' Association, Thirty-First Annual Report upon the Working of the Boiler Explosions Act, June 1912–June, 1913. Manchester, England, no date. (From the Chief Engineer.)

Mead-Morrison Manufacturing Company, Catalogue "S" 2 of Steam Hoists. Boston, no date. (From the Company.)

Missouri Botanical Garden, Annals, vol. ii, Nos. 1 and 2. St. Louis, Mo., 1915. (From the Board of Trustees.)

Morse Twist Drill and Machine Company, Catalogue of Drills, Reamers, Dies, Machinery and Machinists' Tools. New Bedford, Mass., 1915. (From the Company.)

National Commercial Gas Association, Lessons on the Utilization of Gas Appliances, I to X, part iii, Practical Educational Courses; Elementary Principles of Combustion and Utilization of Energy, part i; Units of Light and Illumination and Principles of Light Distribution, part ii; Tables and Glossary, part iii; The Gas Equipment of the Home. New York, no date. (From Mr. Louis Stotz, Secretary.)

New Jersey Geological Survey, Bulletin 13, Indian Habitations in Sussex County, New Jersey; Bulletin 14, The Geology of New Jersey. Union Hill, N. J., 1915. (From the Survey.)

New York Department of Efficiency and Economy, Annual Report. Albany, 1915. (From Prof. Arthur H. Blanchard.)

North Western Expanded Metal Company, Designing Data for Reinforced Concrete. Chicago, 1914. (From the Company.)

Oberlin College, Bulletin and Annual Catalogue. Oberlin, Ohio, 1915. (From the College.)

Ohio Agricultural Experiment Station, Technical Bulletin No. 5, Phosphorus Compounds in Animal Metabolism. Wooster, 1914. (From the Station.)

Ohio Locomotive Crane Company, Catalogue of Locomotive Cranes. Bucyrus, no date. (From the Company.)

Ontario Department of Agriculture, Forty-fifth Annual Report of the Entomological Society, 1914. Toronto, 1915. (From the Department.)

Oregon State Immigration Commission, Oregon Almanac, 1915. Salem, 1914. (From the Portland Chamber of Commerce.)

Pennsylvania Department of Forestry, Report, 1912–1913. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania State College, Report, 1912–1913. Harrisburg, 1914. (From the State Librarian.)

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Philadelphia City Trusts, Forty-fifth Annual Report of Board of Directors, 1914. Philadelphia, 1915. (From the Board.)

Philadelphia Department of Public Works, Report on the Collection and Treatment of the Sewage of the City of Philadelphia. Philadelphia, 1914. (From Mr. George S. Webster.)

Philadelphia Electric Company, Current News, vols. 7–8 and 9–10, 1913–1914. Philadelphia, no date. (From the Company.)

Pridmore, Henry E., Catalogue No. 8 of Molding Machines. Chicago, Ill., no date. (From Mr. H. E. Pridmore.)

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Tokyo Imperial University, Calendar, 1913–14. Tokyo, no date. (From the University.)

United States War Department, Report of the Tests of Metals and Other Materials, 1914, Washington, 1915. (From the Department.)

University of Michigan, Catalogue. Ann Arbor, 1915. (From the University.)
University of Oklahoma, General Catalogue. Norman, 1915. (From the University.)
Victorian Institute of Engineers, Proceedings, vol. xiii. Melbourne, 1913. (From the Society.)
Vulcan Engineering Sales Company, Catalogue No. 3 of Riveters. Chicago, Ill., 1915. (From the Company.)
Watson-Stillman Company, Catalogue No. 92 of Forcing Presses. New York, no date. (From the Company.)
Wesco Supply Company, Catalogue No. 200 of Electrical Goods. St. Louis, no date. (From the Company.)
Western Australia Geological Survey, Bulletin Nos. 56, 57, 59, and 61. Perth, 1914. (From the Survey.)
Western Society of Engineers. Year Book. Chicago, Ill., 1915. (From the Society.)

BOOK NOTICES.

THE CHEMISTRY OF THE CYANOGEN COMPOUNDS AND THEIR MANUFACTURE AND ESTIMATION. By Herbert E. Williams. Philadelphia, P. Blakiston's Son & Co., 1915. Pages i–viii, 406 and Indexes. 8vo. Price, $3.50.

The introductory paragraphs of this work give a short history of the development of our knowledge of an interesting and important group of substances which were long considered as one of the connecting links between organic and inorganic compounds, at least so far as descriptive chemistry is concerned. From this historical summary we learn that the first step was the production of Prussian blue by Driesbach in 1704, and that Macquer, about a half century later, obtained potassium ferrocyanide. An interesting sidelight is thrown on the state of chemistry at that time by the fact that Macquer called the substance "phlogisticated alkali." Scheele obtained hydrogen cyanide in 1782; Gay Lussac prepared free cyanogen in 1815.

The work is divided into three sections, devoted, respectively, to: Chemistry of the cyanogen compounds, manufacture and applications of cyanogen compounds, analysis of cyanogen compounds. Many of the cyanides, ferro- and ferricyanides are described, and much information given concerning other complicated derivatives (cobalti- and platinocyanides), thiocyanates and fulminates. To the chemist who has not followed closely the development of this department, the references to the carbonylferrocyanides will be somewhat astonishing. Ammonium carbonylferrocyanide, for example, is $(NH_4)_2Fe(CN)_5(CO)3H_2O$, and when we come to the diethylaniline and dimethylaniline derivatives the complication is great. It is interesting to write the formula of the ammonium compound empirically, and note how incomprehensble it is: $C_6H_{15}N_4FeO_4$.

A highly commendable feature is the correctness of nomenclature. It is up to date. Such solecisms as "cyanate of potash" and "potassium sulphocyanide," which are so common in present-day works of British provenance, are not found in this work. It is a valuable contribution to an important and complex department of applied chemistry.

HENRY LEFFMANN.

EXPLOSIVES: THEIR MANUFACTURE, PROPERTIES, TESTS, AND HISTORY. By Arthur Marshall, A.C.G.I., F.I.C., F.C.S., Chemical Inspector, Indian Ordnance Department. Philadelphia, P. Blakiston's Son & Co., 1915. 605 pages and indexes. 8vo. Price, $7.

Few works of a purely technical character could just now attract more general attention, but it is not of any popular interest that this review should speak. The work is by an expert and represents a needed addition to the literature of an extensive and important department of applied chemistry. The attention of people at large is usually directed to the use of explosives for destructive purposes, but those familiar with the subject know that by far the more important use is in constructive operations, in which, at most, the destruction is only preliminary to improvement.

The work is comprehensive, including many details of the manufacture of the materials used in the making of explosives, as well as the process of manufacture of all leading types. Considerable attention is given to the theoretical side of the science, and a summary of the history of the development of explosives as used in war. In the latter we find, as might be expected, that some of the "Tales of our Grandfathers" are without basis, notably the story that the Chinese used gunpowder at a very early date. Mr. Marshall, however, shows that they did use potassium nitrate about the middle of the eighteenth century. The legend as to the great antiquity of Chinese gunpowder seems to have been due to mistranslations—depending on misunderstandings—by the Jesuit missionaries. Roger Bacon knew methods of preparing explosives with charcoal, sulphur, and saltpetre. Incidentally, Mr. Marshall's summary shows the truth of the current saying that gunpowder was invented by a monk and the percussion cap by a minister.

On taking up the book the reviewer was reminded of the opening lines of Macaulay's review of Nares's "Life of Lord Burghley," in which are given the volume and weight of the book. Mr. Marshall's book is no *vade mecum*. It has a volume of about two litres and weighs over two kilos. Bulk and weight are due largely to the use throughout of heavy surfaced paper, a procedure that the reviewer thinks might easily have been avoided.

A short article on fireworks is included, but no mention is made of photographic flash-powders. It seems to the reviewer that these deserve considerable attention. They are extensively used, many forms have been prepared, and much destruction of life and property has been occasioned by them. In Philadelphia alone nearly a dozen deaths have been caused by the mixtures. A good account of preparations now offered by leading firms should certainly be included in a work of such comprehensive character as this.

A great disappointment is the neglect of the modern standard nomenclature of chemical compounds. It is surely time that such terms as "chlorate of potash," "acetate of lime," and "chloride of sodium" should be avoided in a scientific work.

A paragraph of much present interest to American readers is the notice of the Louisiana sulphur mines. The deposits are at such a depth as to render ordinary mining methods too expensive, but by an ingenious use of high steam the sulphur is brought to the surface and collected. The perfection of the method is due to Hermann Frasch. Until these mines were opened the world's supply of free sulphur was almost entirely from Italy, but several hundred

thousand tons are produced each year in Louisiana, and the United States has not only enough for itself, but exports such large amounts that the Sicilian mines became unprofitable. The Italian Government has taken over the operation of these, and Mr. Marshall states that the present condition of the workers is better than ever before.

HENRY LEFFMANN.

SPENCER FULLERTON BAIRD, A BIOGRAPHY, INCLUDING SELECTIONS FROM HIS CORRESPONDENCE WITH AUDUBON, AGASSIZ, DANA AND OTHERS. By William Healey Dall, A.M., D.Sc. Philadelphia, J. B. Lippincott Company, 1915. 450 pages, 19 illustrations. 8vo. Price, $3.50.

The subject of this work was the second secretary of the Smithsonian Institution, and organizer and first commissioner of the United States Commission of Fish and Fisheries. He died at Wood's Hole.

The data were largely collected by his daughter, Miss Lucy Hunter Baird, and to Dr. Dall was committed the task of selecting, arranging, and preparing them for publication. The forepart of the book contains a summary of the genealogy, and some incidents of the early life. The childish traits and early experiences of those who have become great are always of interest, and usually exemplify the truth of the adage that "truth is stranger than fiction." Perhaps the vividness of such recital is better preserved in an autobiography, if the editors have not used the blue pencil freely.

The letters that pass between distinguished men and women of similar tastes throw much light on the development and methods of human thought, yet it seems probable that, except in the case of those who have profoundly modified the general course of human events, comparatively few care to read the collection. By founding the Commission of Fish and Fisheries, Baird did much greater service to mankind than Peary did by reaching the Pole, or Roosevelt by shooting game in Africa and South America, yet thousands of people know of the exploits of the two latter for one who knows the service of the former.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Test Methods for Steam Power Plants: A Reference Book for the Use of Power-station Engineers, Superintendents and Chemists, by Edward H. Tenney, B.A., M.E. 224 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1915. Price, $2.50 net.

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Calculation of Illumination with Indirect or Semi-indirect Light Sources. RICHARD C. POWELL. (*Electrical World*, vol. 65, No. 23, 1463.)—Calculation from the photometric curve and height of a source of light is a well-known and commonly-used method for predetermining the distribution and intensity of illumination from a direct light source. But when indirect or semi-indirect units are employed, the usual course is to rely upon judgment or a preliminary test which often is not convenient. In the method of calculation developed it is necessary to know only the photometric curve, the coefficient of reflection for the secondary source (usually the ceiling), the distance of the unit below the ceiling, and the height of the ceiling above the plane of illumination. While this method is not so simple as in the case of direct units, still it is believed to be sufficiently so to make it of considerable value to those planning lighting installations.

Outline of Method.—The light unit produces on the ceiling a secondary light source in the form of a circular disk, generally of non-uniform intensity. This disk may, however, be considered as made up of a number of circular annuli or rings of uniform intensity of illumination. The effect may also be considered the same as that which would be produced by a number of uniformly-illuminated concentric disks of varying radii. By calculating each disk separately and adding the results there is obtained approximately the illumination due to the ceiling. By taking a sufficiently large number of disks we may make the approximation as close as desired, but in practice it is usually sufficient to take four.

CURRENT TOPICS.

Production and Shipments of Portland Cement, 1914.—Figures gathered by United States Geological Survey show decrease in both quantity and value of output. The total production of Portland cement in the United States in 1914, according to Ernest F. Burchard, of the United States Geological Survey, was 88,230,170 barrels, valued at $81,789,368; the production for 1913 was 92,097,131 barrels, valued at $92,557,617. The output for 1914 represents a decrease in quantity of 3,866,961 barrels, and a decrease in value of $10,768,249. The value assigned to the production is computed on the basis of 92.7 cents a barrel, or the average value of the Portland cement shipped in 1914.

The shipments of Portland cement from the mills in the United States in 1914 amounted to 86,437,956 barrels, valued at $80,118,475, compared with 88,689,377 barrels, valued at $89,106,975, shipped in 1913. This represents a decrease in quantity of 2,251,421 barrels, and in value of $8,988,500. The average factory price per barrel in bulk for the whole country in 1914 was 92.7 cents, compared with $1.005 in 1913, a decrease of 7.8 cents a barrel. This price is about 11.8 cents higher than the average price in the Lehigh District and is near the average price in New York, Illinois, Iowa, the Southeastern States, and the Plains States, but falls 42.5 cents below the average price received in Utah, where Portland cement brought the highest figure during the year.

Among the States there were unimportant changes in rank as cement producers. Pennsylvania and Indiana held first and second places respectively, as for many years, but both of these large cement-producing States suffered an appreciable reduction of output. In 1913 the output of California exceeded that of New York and Illinois, but in 1914 this State dropped from third to fifth place. New Jersey dropped from seventh to ninth place, having been passed by both Michigan and Iowa in 1914. The State of Kansas, which has attracted considerable attention in the cement world, first because of the rapid development of the industry within its borders on account of the proximity of abundant supplies of suitable raw material and cheap natural gas, and later because of the waning of the gas supply and the consequent increase in cost of manufacture of cement which resulted in curtailment of output, maintained its rank of tenth among cement producers and suffered but little reduction of output, although the price of cement here fell considerably below the average. Iowa and Ohio both showed gratifying increase in output and appear also to have kept prices up more successfully than many other States. In the Far West, in Washington, conditions were brought into better balance by a considerable curtailment of production and an increase

in shipments, although prices fell heavily; in Utah production was largely and shipments slightly increased, and prices were also increased. The only other States showing increase of prices were New Jersey and Texas.

Of the twelve commercial districts into which the United States is divided, there was an increase in production in five—New York, Michigan-northeastern Indiana, Maryland-West Virginia, Iowa-Missouri, and the Rocky Mountain States—and an increase in shipments in seven—New York, Ohio-western Pennsylvania, Michigan-northeastern Indiana, Kentucky-southern Indiana, Maryland-Virginia-West Virginia, Iowa-Missouri, and the Rocky Mountain States. There were decreases in production in seven districts—Lehigh, Ohio-western Pennsylvania, Kentucky-southern Indiana, Illinois-northwestern Indiana, Tennessee-Alabama-Georgia, Great Plains, and Pacific coast—and decreases in shipments in five districts—Lehigh, Illinois-northwestern Indiana, Tennessee-Alabama-Georgia, Great Plains, and Pacific coast. The largest percentage of increase of production was reported from New York, but the increase in shipments in that district was only half as great. The districts that showed the heaviest percentages of decrease in both production and shipments were the Tennessee-Alabama-Georgia district and the Pacific coast.

Production of Pyrite and Sulphuric Acid in 1914.—The production of pyrite in the United States in 1914, according to W. C. Phalen, of the United States Geological Survey, was 336,662 long tons, valued at $1,283,346. In 1913 the production was 341,338 long tons, valued at $1,286,084. There was a decrease, therefore, in 1914 of 4676 long tons in quantity, or slightly more than one per cent., and of $2738 in value, or but one-fifth of one per cent.

Virginia is the leading State in both production and value. The output of this State diminished slightly in 1914 as compared with 1913. The output in California showed a slight gain. There was a substantial gain in the production in New York, which, though ranking third among the States in production, stands second in value. In Illinois, where pyrite is a by-product obtained in connection with coal mining, the output more than doubled compared with 1913. In Wisconsin there was a decreased production. In Georgia there was a slight increase. In both Ohio and Missouri there was a decline in production, and in Indiana, where, as in Illinois and Ohio, the pyrite is obtained in connection with coal mining, there was a slight increase as compared with 1913.

Imports of Pyrite.—The imports of pyrite for consumption during the calendar year 1914 were 1,026,617 long tons, valued at $4,797,326. These figures show a notable increase compared with the imports of 1913, which were 850,592 long tons, valued at $3,611,137. The increase in imports in 1914 amounted to 176,025 long tons, and in value to $1,186,189.

Production of Sulphuric Acid.—According to actual returns for the year 1914, the production of sulphuric acid in the United States was 3,762,417 short tons of 50° acid, valued at $24,163,331. This is exclusive of 21,993 short tons of fuming acid, valued at $316,596, but the figures given above include by-product acid—that is, acid obtained in the smelter industry. The acid produced at copper and zinc smelters in 1914 amounted to 950,798 short tons of 50° acid, valued at $5,190,293. The entire production of acid by grades is tabulated below:

PRODUCTION OF SULPHURIC ACID IN THE UNITED STATES IN 1914 BY GRADES, IN SHORT TONS.

Grade	Quantity	Value	Price per ton
50° Baumé	1,628,402	$ 9,712,056	$ 5.96
60° Baumé	551,955	3,376,242	6.12
66° Baumé	916,192	10,509,471	11.47
Other grades	65,890	882,158	13.39
Total	3,162,439	$24,479,927	$ 7.74
Total reduced to 50° Baumé acid	*3,762,417	*24,163,331	6.42

*Exclusive of 21,993 short tons of fuming acid, valued at $316,596.

PRODUCTION OF SULPHURIC ACID FROM COPPER AND ZINC SMELTERS IN 1913 AND 1914, IN SHORT TONS (REDUCED TO 60° BAUMÉ ACID).*

Source	1913			1914		
	Quantity	Value	Price per ton	Quantity	Value	Price per ton
Copper smelters	336,019	$2,205,627	$6.56	348,727	$2,215,690	$6.35
Zinc smelters	296,218	2,140,645	7.23	411,911	2,974,603	7.22
Total	632,237	$4,346,272	$6.87	760,638	$5,190,293	$6.82
Total acid reduced to 50° Baumé	790,296	.....	.....	950,798	.....	.....

*The acid reported to the Survey includes strengths rated at 50°, 53°, 55°, 60°, and 66° Baumé, and a small quantity of electrolyte and oleum. All strengths, with the exception of the electrolyte, have been reduced to both 50° and 60° Baumé, as given in the table.

Developments in Heating and Ventilation. A. H. BARKER. (*Journal and Transactions of the Society of Engineers (Incorporated)*, vol. vi, No. 5.)—It is an undeniable fact that a room filled with air which, so far as chemical analysis can detect, is absolutely pure may feel very stuffy. For instance, the House of Commons, on the ventilation of which the author has experimented for many months for the Committee of the House, the air in the debating chamber is, chemically speaking, as pure as in any room in the

world. Fresh air simply pours into it in extravagant volumes. In a moderately full house there are no less than 13,000 cubic feet of air supplied per head per hour. Yet it produces, without any possible doubt, the effects which we are accustomed to think of as associated with defective ventilation—lassitude, sleepiness, infection, and so forth. Complaints are loud and quite general. A room may, on the contrary, feel fresh and sweet in which, judged by chemical standards, the air is very bad. The author has analyzed air containing 25 volumes per 10,000 of CO_2 which felt as fresh as a spring morning, although 10 volumes is regarded as the extreme allowable impurity in current science. There must be some combination of chemical or physical conditions which accounts for the effect, so far as it is objective; when it is purely subjective, of course, it is impossible to analyze the effect. Nobody up to the present has ventured to specify what is that combination.

Examining X-ray Plates by Mercury-vapor Lamps. ANON. (*Electrical World,* vol. 65, No. 23, 1475.)—For the minute examination of details of structure in fabric many advantages are claimed for monochromatic light, since with it all rays which make up the image are brought together in the "plane" of the retina without the possibility of effects of color aberration. Hence vision becomes much "sharper." An interesting application of this advantage is in its use in hospital X-ray wards for the inspection of skiagraph negatives by the surgeons. A large installation of this kind was recently completed at the Cook County Hospital, Chicago. According to the physician in charge, much sharper inspection, and consequently better diagnosis of the faint images and shadows of the negative, is secured by the monochromatic light of the mercury arc than with the continuous-spectrum illumination formerly obtained from incandescent-filament units.

A Galvanic Cell Which Reverses its Polarity when Illuminated. A. A. C. SWINTON. (*The Physical Society of London,* vol. xxvii, part iii.)—If two plates—one of zinc and the other of tinned copper coated on one surface with selenium and varnished with enamel over the remainder of its surface—are immersed in tap-water, the electric current through a galvanometer connected to the plates shows that in the dark the zinc is electro-positive to the selenium, while the result of light falling on the selenium is to increase the effect. If, however, instead of zinc, carbon or copper is employed for the non-coated plate, the interesting result is obtained that, while the selenium proves to be electro-positive to the carbon or copper in the dark, it immediately becomes electro-negative to carbon or copper the moment it is illuminated, this being easily shown by the deflections of the galvanometer in contrary directions as the light is turned on or off.

The Distribution of Heat in the Cylinder of a Gas Engine. A. H. GIBSON and W. J. WALKER. (*The Journal of the Institution of Mechanical Engineers,* No. 5, 1915.)—The paper deals with the results of a series of experiments on heat-flow in a gas-engine cylinder as affected by the variation of speed, load, compression ratio, and gas mixture. The principal point under investigation was to determine the effect of turbulence on this heat-flow. The trials were carried out on a " National " gas-engine of 30 b.h.p., peculiarly well suited for the investigation, a special water-jacketing arrangement being provided whereby exhaust and barrel heat losses are separated. Some 130 trials were carried out. The most important points brought out in the investigation may be summarized as follows: *The mechanical efficiency* (1) diminishes as the ratio air : gas increases, (2) diminishes as the speed increases, (3) is sensibly independent of compression ratio. *The thermal efficiency,* measured on the indicated horse-power, (1) attains a maximum with an air : gas mixture of about 10 : 1; (2) diminishes as the speed increases. *Percentage exhaust losses* (including heat to exhaust-valve jacket) (1) diminished as the load increases; (2) diminish very slightly as the ratio air : gas increases; (3) increase as speed increases; (4) increase as the compression ratio increases. *Percentage jacket losses* (barrel and breech only) (1) increase with the load; (2) diminish as the ratio air : gas increases; (3) diminish as the speed increases; (4) are sensibly independent of compression ratio. It is interesting to note that the rate at which heat is lost to the barrel-jacket is much greater at high speeds than at low speeds, notwithstanding the lower explosion temperatures which accompany the higher speeds. This effect is apparently due to the predominating influence of turbulence, causing an increase in the effective conductivity of the working fluid. The final portion of the paper describes how heat balance sheets were made up to the end of expansion for each test by obtaining the internal energy of the fluid at the end of expansion. An interesting point brought out by these balance-sheets appears in the fact that with ordinary mixtures and compression ratios they agree very well with those of the ordinary commercial type of engine, obtained by measuring the i.h.p. and jacket heat and estimating exhaust losses by difference. For fairly rich mixtures and lower compression ratios, however, the agreement is not so good, the jacket losses as usually measured in an ordinary engine always being in excess of those more correctly computed from the internal energy of the gas.

Noise in Gearing. ANON. (*English Mechanic,* vol. ci, No. 2616, 325.)—It is not always easy to trace noise to its source, for it is often the combined effect of several small individual causes, and not infrequently an incorrect conclusion is reached and a wrong remedy applied. Two manufacturers, both producing a similar machine, claim to have minimized noise by entirely opposite means, both main-

taining their own solution the best possible. One had adopted an extra-long tooth, the other an extra-short tooth. The author points out that the most prolific cause of noise is inaccuracy of workmanship, both in the gears themselves and in their mounting. He describes at considerable length precaution to be observed in attaining accuracy essential to good results, whatever be the form of tooth adopted or the material.

The Second Pan-American Scientific Congress.—During the present year two important Pan-American gatherings convene in Washington under the auspices of the Government of the United States. The first of these, the Pan-American Financial Conference, occurred the week of May 24, 1915. Of greater interest to the educational world, however, is the Scientific Congress that will convene in Washington, beginning December 27, 1915, concluding its sessions January 8, 1916. The first congress of this name was held in Santiago, Chile, in 1908. This congress was well attended by visiting delegates from the United States. On its adjournment, entirely unsolicited on the part of the latter, Washington was designated as the place of meeting of the second congress. The Scientific Congress will concern itself with the constructive discussion of the grave economic problems with which the western hemisphere has been confronted by the war in Europe that invite the serious attention of scientists and experts in the various fields of applied science, as well as with advances in the domain of pure science made since the last congress in Santiago, Chile. Science is comprehensively defined by the congress, and includes, authropology, astronomy, agriculture, education, engineering, jurisprudence, chemistry, medical science, and commerce. The significance of the congress through the importance of the above subjects is greatly enhanced through the international reputation of the persons chosen to arrange for the program of the different sections of the congress, most of whom have an intimate first-hand acquaintance as well with the local resources, development, and scientific interest in the various Latin-American countries.

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